TELESCOPE MAKING 18

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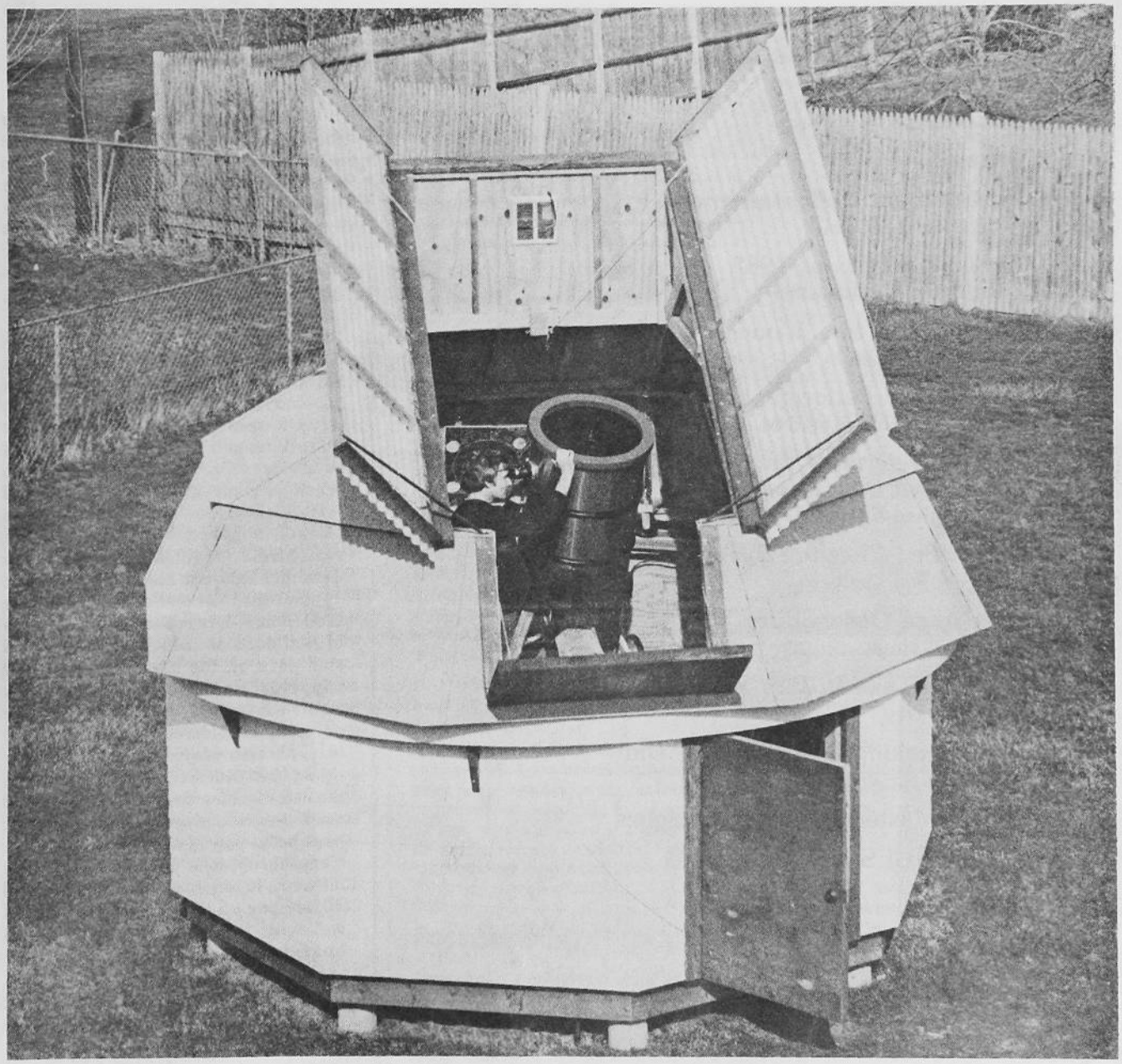
The magazine *for*, *by*, and *about* telescope makers!

Winter 1982/83



TELESCOPE MAKING

The magazine *for, by,* and *about* telescope makers!

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Editorial

Well, what can I say? TM is running late again, by about 4 weeks, and if the presswork is slow, you may receive it as much as 6 weeks behind schedule. I've begun to suspect it's part of the Winter issue — maybe the boards-to-press deadline of December 21 is not realistic in view of all the holiday cheer! If things go according to last year's experience, I'll be all caught up by the Fall issue.

You may notice that the Blue Pages Advertising section has gotten bigger, which is a very healthy sign in a flagging economy, a sign that I hope means that advertisers are, at last, figuring out that we're here, and TM is a good vehicle for small specialized companies trying to reach very specialized buyers. Our ad rates are low, too. Interested advertisers should contact Mary Pierson at AstroMedia (414-276-2689) — please note that I do not handle this area.

You'll also notice that our body type is changing — this issue is a mishmash of stuff done on the old typesetter and stuff done on the new typesetter. Our body type, for those who wish to know such things, is Souvenir, a face normally considered inappropriate for text. We also use Serif Gothic Bold for titling, but that will end soon because the new machine does not have it. You'd think that Souvenir would be Souvenir anywhere you get it, but it's not. Compugraphic's Souvenir is quite different. In any case, the next issue will all be done on the new typesetter, and we will be restored to blessed homogeneity.

CCCC will be in the next issue again. Please send your programs to Bob Cox; if you send them to me, I send them to him, but it takes longer.

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On article submissions, for those who have asked: there are no rules. Send me the article; I'll tell you whether we'll publish it. It really helps to have it typed since it's easier to read, or at least there are no totally ambiguous words. Line drawings done with a nice juicy black felt pen come out pretty well, but if you know how to use a technical pen, please use it. For photos, I prefer 5x7 or 8x10 black and white prints, fairly contrasty, but can do okay with 3x5 color prints if they are sharp. Color slides present problems with burned out highlights and inky shadows, but can be used. What we do is have 3x5 color prints made. We'd prefer that you have the prints made and send them to us. Hang on to your originals. Polaroids usually reproduce looking pretty mushy, but I'll use them. We pay a $10 honorarium for your article to help you cover the cost of making a submission. We send you a contract for rights to the article and the right to publish your name and address (which the privacy laws require), but if you want to publish the article elsewhere, we grant permission automatically.

We have lots of good stuff coming up in the next few issues. TM#20 will mark the completion of five years of publishing, so we may try to do a special big issue. No promises, though.

Keep on building! Keep on observing!
Sincerely,

Richard Berry

Richard Berry
Editor

Letters

Auto-Guiders Wanted

Dear Sir / I take this opportunity to congratulate you for your very interesting magazine which, by the way, has become very popular with amateur astronomers here in Australia.

I would like to see — and I am sure a lot of other people would too — an article or two on automatic guiding systems. I'd like them to have lots of drawings and photographs for those of us who are not mechanically minded and do not have facilities handy to have the work done for them. (Anyhow, that would prove to be expensive.)

Just a comment: sometimes looking at some of the telescopes in TM, it is hard to believe that they are made from salvaged parts or scrap. Please do not take this as a criticism of your publication: it is a thought spurred by my own situation. I have found it very hard to build something using so-called salvage material. Evidently I have not tackled the problem the proper way.

Anyway, I am looking forward to the next issue; meanwhile, I wish you all the best.

John Izzo
15 Packham Street
Boxhill North VIC 3129
Australia

— I've never made really effective use of salvage myself. I'm inclined to think that you need some machine shop facilities (not a complete shop, mind you) to cut it up, turn it to size, and add holes in the right spots. Electronics salvage requires the right backup knowlege; see Remaklus' article in TM#15.

Fast Slewing Needed

Dear Sir / I am constructing a 12.5-inch Newtonian-Cassegrain, which I will use for observing faint variables. I want to be able to slew mechanically in R.A. to center stars. Most electronic VFO units sold are for photographers, and are much too slow for my purposes. I think it might be best to introduce a differential into the gear train. I would be most grateful if you, or any reader, could recommend a source where I might buy a small mechanical differential.

Rev. Patrick J. Madden, Chaplain
St. Frances Cabrini Hospital
3330 Masonic Drive
Alexandria, LA 71301

— Check Perry Remaklus' article in TM#15 for tips on buying items such as differentials as "junk"; any reader knowing a good source of such unit, please let Rev. Madden and TM know about it.

Sweet Memories

Dear Sir / I have enjoyed TELESCOPE MAKING since it started and hope it continues, for everyone's benefit, for years to come.

I would especially like to see more technical information on optics of all types of telescopes. There are a lot of computer owners out here who would like to see more programs written in MICROSOFT BASIC that pertain to the interfacing of a computer to the telescope.

With today's micro/mini computers, it is now possible to let these computers analyze data that, less than ten years ago, would have taken years. My telescope set-up has cost me over $30,000 over 25 years — yet for about $500 I bought a computer that five years ago would have been too big, in memory size, for just keeping track of where a telescope was pointing. I'm sure there are routines for computers to make an alt-azimuth telescope track like an equatorial — with better accuracy than the most sophisticated mechanical/electrical combination on the market today.

CPUs being built today have 256 kilobytes, and that will be the standard in computers next year. I own two Winchester hard storage drives with a combined capacity of 24 Megabytes.

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Notes on an 8″ Achromatic Objective

Much has been written about grinding and polishing parabolic mirrors — and since the tasks involved in the fabrication of an achromatic objective are very little different, I will just touch on those critical points that differ. Also, fabricating tripods, mounts, tubes, etc., has also been covered extensively in the literature, and I will, therefore, restrict this article to the "real meat" of the optical fabrication task.

In the fabrication of my objective, it is of interest to note that all work was accomplished in an ordinary garage and done by hand, from the first rough grinding through final figuring. All test equipment was fabricated by the author, including a novel photometer for optical testing.

Grinding

There are two major differences in working the surfaces of an objective versus a mirror. First, since you need to fabricate accurate radii on an objective lens, a spherometer is virtually mandatory. This device is easily constructed, and provides the necessary check on the radii of the spherical surfaces by measuring the sagitta as grinding proceeds. It is advisable to hold the calculated "sag" to better than .001″.

Second, the edge thickness error, or wedge, must be minimized. An edge thickness measuring device is necessary if minimal residual aberration is to be expected. Edge thickness around each element should be held to ± .002″.

However, with these exceptions, all other grinding operations are pretty similar to grinding a mirror — but there are lots of small departures. One is that you must maintain the center thickness of each element during the rough grind while changing the radius. This is accomplished by the use of chordal strokes. After determining a proper thickness-to-diameter ratio, one does not want to reduce the center thickness below specified tolerance. Chordal strokes will reduce unnecessary removal of glass from the center of each element.

Polishing

Here again we see a difference between the mirror and the objective. In grinding an objective, we will need two to four tools depending on our lens design, and when polishing, we will need at least three laps.

In polishing, we're beyond the point of mechanical measurement for sphericity or wedge and must commence optical measurement of same. Our method of testing the lens is the autocollimation method, using either a Focault test and/or a Ronchi test. Upon completion of polishing, the surfaces, of course, will not be perfectly spherical.

Figuring

We must now determine how to best figure our lens to achieve an integrated spherical system. I use this terminology since it is not necessary to figure each surface or, for that matter, each element. We can choose one surface and correct for all four.

Here again, we're on familiar ground, assuming you have figured a mirror, except in reverse order. Whereas we figure mirrors by changing a sphere to a paraboloid, in the case of the objective, we change our system of four surfaces by correcting one surface, bringing the system from a paraboloid, hyperbola, or what-have-you, to an effectively nulled system.

Once having achieved our best results in reaching system sphericity through the use of the autocollimation tests coupled with the appropriate polishing steps, we are ready to do final figuring.

Removing Residual Aberration

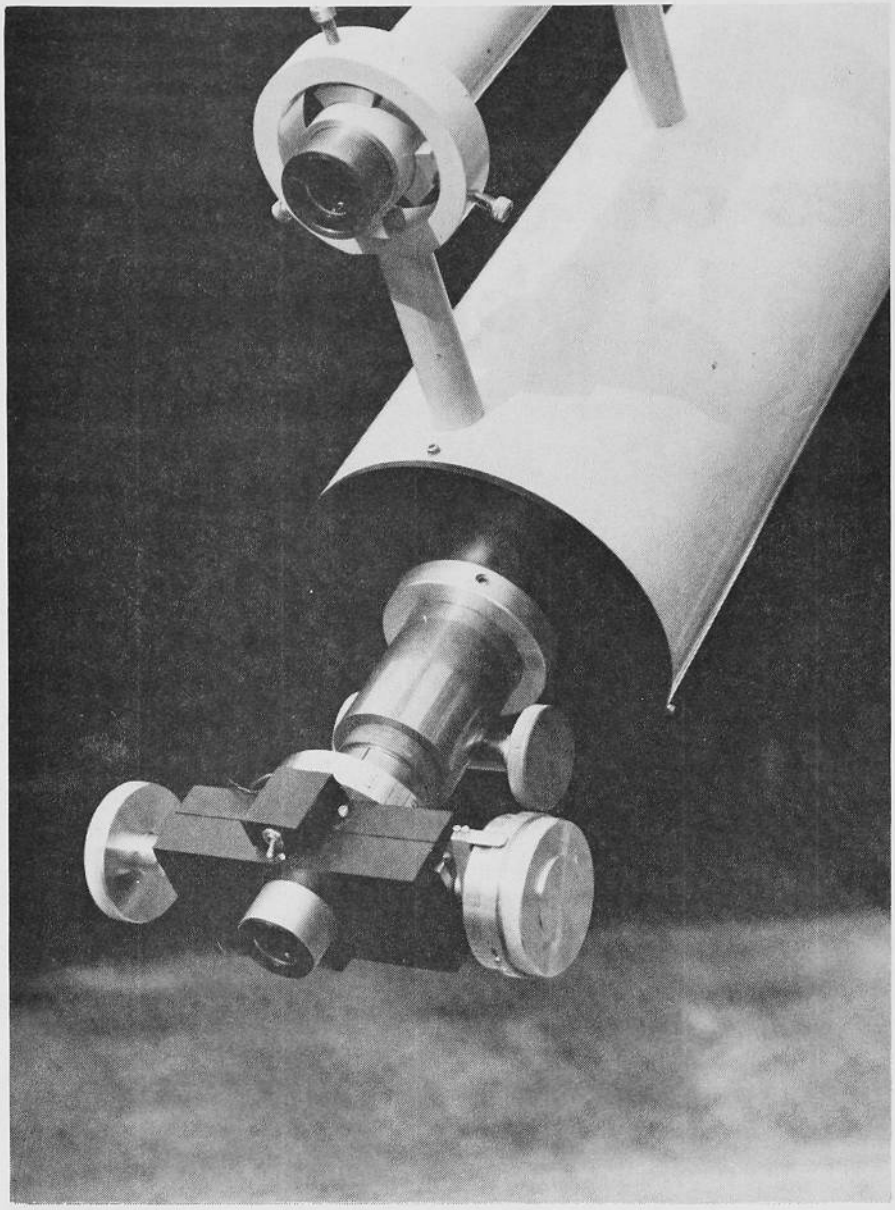
This is the point where the men are separated from the boys as optical technicians or "artists in glass." We must now determine the primary residual aberration and correct it. The chances seem to be about 20 to 1 that there will be some astigmatism, most likely introduced during polishing by flexure of the lens elements.

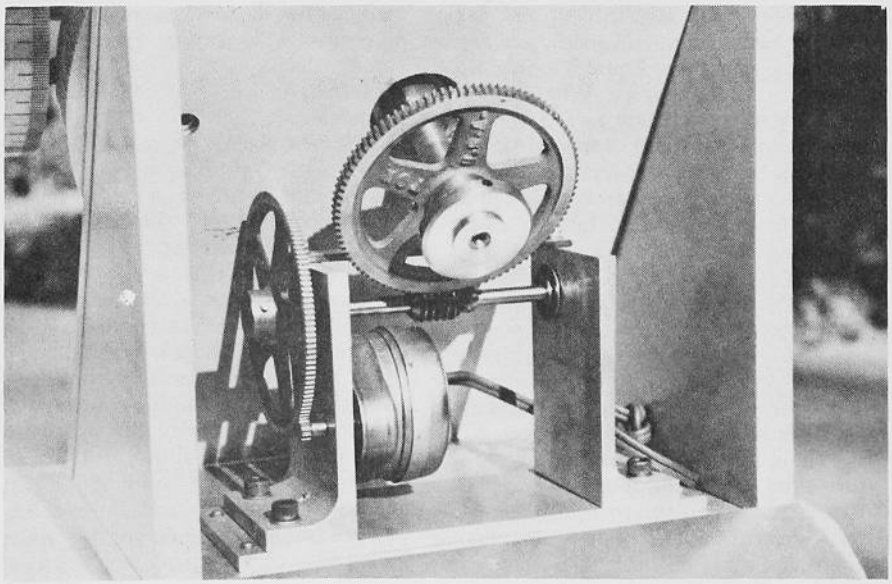
My test for astigmatism uses autocollimation and requires a series of zonal focal measurements across different diameters. The idea is to place a circular mask with holes in it over the lens to admit light from narrow zones of the lens. We then determine the exact radius of that zone at a series of different positions around the lens to derive a radial map of zonal focal lengths.

For my 8″ diameter lens, I made a mask covering it to the edge. I cut two ¾″ diameter holes on the same axis, the centers of which lay on a 6″ diameter. This mask was placed in front of the lens so that it could be rotated concentrically on the same center as that of the lens. I determined the radii with an eyepiece instead of a knife edge or ronchi ruling. Do this by bringing to focus the two images of a pinhole source from the mask holes. Here is where the two-hole technique is the most help — they act much like a rangefinder image as they come to focus.

Starting at 0°, or axis #1, and proceeding through 22.5°, 45°, and so on around all 8 axes, I measured the focal length variation of each axis. I then plotted the variations — the resulting curve yields both the degree of astigmatism as well as the astigmatic axes.

Having run such a test, you would most likely find the telltale periodic curve depicting flexural astigmatism. You now try to minimize, by cancelling opposing errors in the elements, the amplitude of the curve. I did this by rotating the crown with respect to flint in 15°-30° increments, each time running the test again and plotting the curve. In so doing, you will find an orientation of the crown to flint that results in the least zonal focal





length deviation.

Next, proceed with correction by polishing stroke changes and/or lap configuration changes. This is an iterative process. Repeat it as required.

Chances of your curve ever becoming truly straight are remote, but you'll want to reduce the double amplitude of the curve to a minimum.

After final correction, I checked my eight-inch lens in a complete telescope configuration. The bench tests had already showed correction for astigmatism good to 1 part in 9600 maximum zonal focal length variation. The lens has excellent double star separation capability, and is very good with other celestial observations. Terrestrial target resolution is better than 1 arc second.

Notes on Tools

A spherometer is only as good as the accuracy of location of its three feet with respect to each other and the dial indicator foot. Shoot for ± .001.

The edge thickness (wedge) measuring tool does not require any critical tolerances since we are not measuring edge thicknesses per se, but rather variation in edge thickness.

The design of the knife edge/Ronchi tester used by me incorporates a simple penlight flashlight coupled with a short length of fiber optic which brings the knife edge and pinhole close together. I made a Ronchi grating using the "wire and frame" approach. The elimination of glass from the grating proved to be a great asset in negating refraction disturbances.

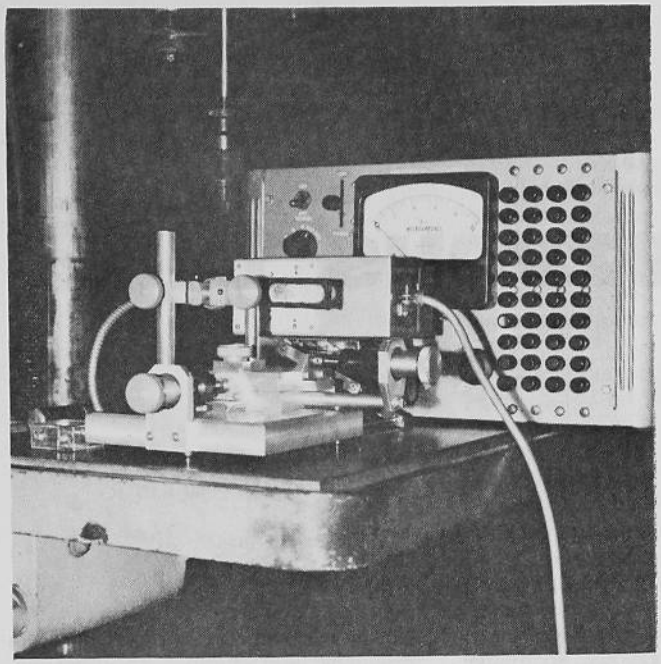
One unique incorporation was the use of ball screws for adjustment of each axis of the tester, though this is certainly not a requirement. By loosening one knurled knob, conversion from knife edge to Ronchi grating is achieved.

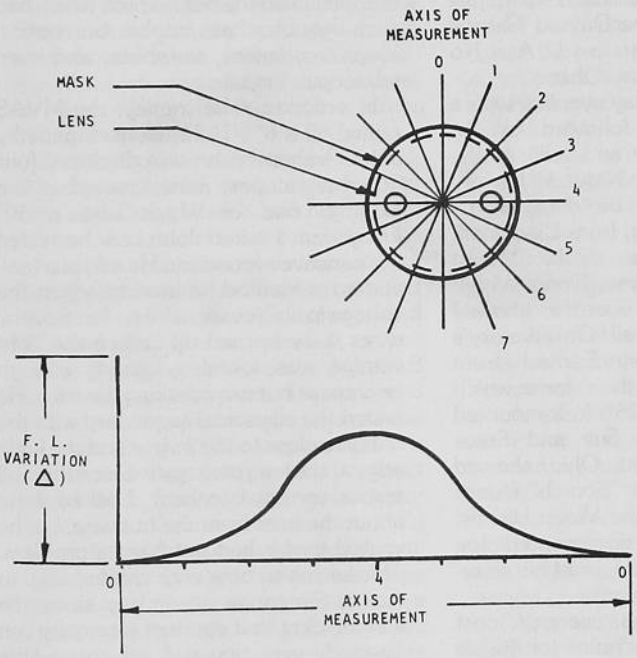
The photometric tester is anything but a must, but possibly significant in optical testing. Why a photometer? It provides a better resolution by photo-optically detecting the diameter of the last circle of confusion in conjunction with the knife edge tester.

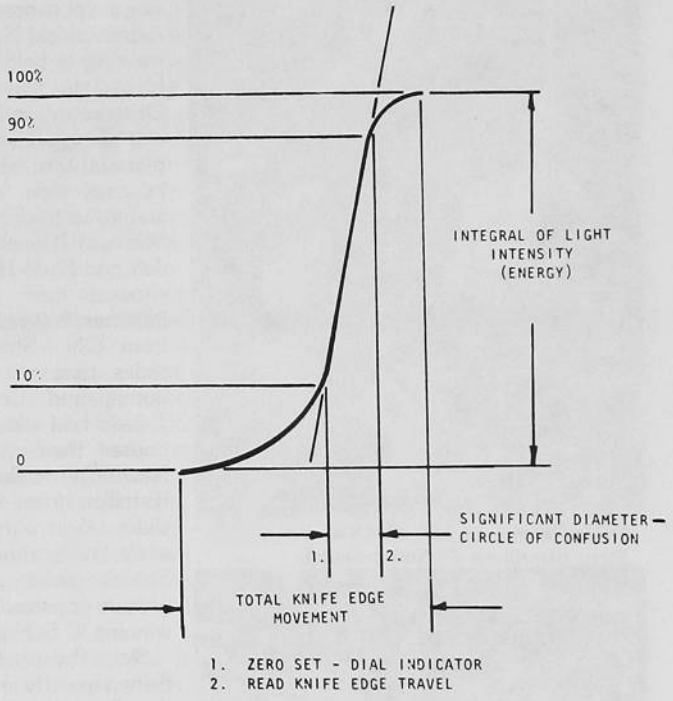
I used a pinhole, the diameter of which is small enough for testing to the defraction limit of the lens system. Where the pinhole image is brought to focus at the plane of the knife edge, I placed the photometer detector centered on the pinhole image and just behind the knife edge.

The detector is a photomultiplier with an appropriate integral high voltage supply. The readout meter's full-scale deflection is ten microamps.

For testing, I then adjusted the meter for full-scale reading. The knife edge is then moved across the pinhole image to cut off its light. In so doing, I watched the meter until I saw a current reduction of







10%, and at this point, set a dial indicator in contact with knife edge cross-axis to zero.

I then proceeded to move the knife edge to further extinguish the pinhole image until the current was reduced by 90%. At this point, I read the dial indicator to obtain the diameter of the circle of confusion containing approximately 80% of the total energy.

In using small pinholes, the movement is only a few thousandths of an inch and should be repeated several times, averaged, then divided by two since the autocollimator technique doubles all aberrations because the light path passes through the lens twice.

The Filar Micrometer

A filar micrometer, of course, must be considered an observing tool rather than a fabrication tool. The one made by me follows classic designs available from the literature. One note of interest might be made in the area of the reticle material chosen. Having tried out spiderwebs, I was looking for an improvement. After testing several materials, I elected to use multi-filament nylon thread (the finest available for fishing rod wrapping). This thread is made up of a dozen or so filaments, .0003″ to .0004″ in diameter. I found the single filament to be an excellent substitute for the historically familiar spun filament.

In designing the lens, I used the basic equations from the literature and did a hand-calculated ray trace. I have also completed a 6″ diameter 120″ focus achromatic objective.

Dain B. Lones
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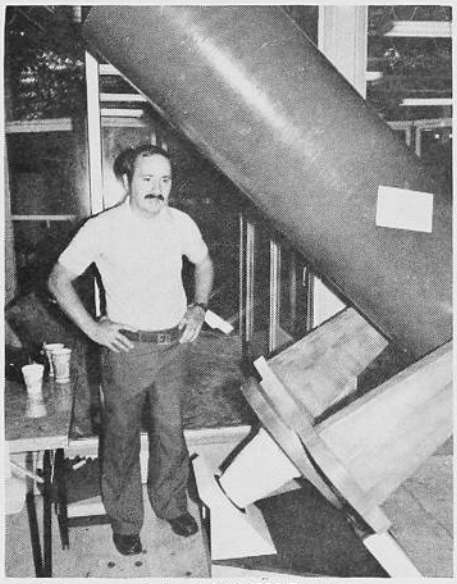
Apollo Rendezvous 1982



Ed Jones and the 16" MVAS scope.
Steve Rismiller's 4" Kutter-Schief.

June 11 and 12 were the dates for this year's Apollo Rendezvous, an annual event sponsored by the Miami Valley Astronomical Society. Each year, this meeting is held in the Dayton Natural History Museum and Apollo Observatory in Dayton, Ohio.

It all began on Friday evening, with a planetarium show followed by an informal slide "show and tell" in the auditorium of the Natural History Museum. It seemed to be "dome night." Jeff and Reda Hutton, from Cincinnati, showed their slides of the Mount Palomar 200-inch dome; Doug Wereb from Ohio State University, showed slides taken of Lowell Observatory's dome; and Courtney Earhart from Toledo had slides of their dome which houses their club's 25" fork-mounted Newtonian reflector. Sue and Steve Rismiller, from Milford, Ohio, showed slides taken with their "Scotch" mount while on vacation in the Virgin Islands. Steve's slides also documented the various construction stages of his prize-winning 4" Schiefspiegler.

Since the weather was overcast, most turned in early in preparation for the big day, Saturday.

Things were already busy when we arrived: the registration desk was surrounded with people waiting to register, so it took a while. I was riding with Jim McKinley from Cincinnati, and right after registering, we set up his 8" Newtonian — but the sheltered porch where the telescopes were displayed had just about filled by 10:00 a.m. Many friends and acquaintances were already there, discussing their new telescopes and exchanging ideas.

From there, we went over to the Apollo Observatory which houses the MVAS 19.5" Cassegrain telescope, optical workshop, and display rooms. I set up my own display of recent Mars drawings and Jupiter photographs. While having our first cup of coffee, we dropped in on the flea market, which had such goodies as books on optics, eyepieces, lenses, tee-shirts, and even telescopes for sale.

In order to raise money, the MVAS raffled off a 6" f/11 Newtonian made by John Graham. John also displayed four other telescopes, none entered in the judging, one of which was a 10" Gregorian. I asked John how he tested the concave secondary. He told of a trial-and-error-method he used to adjust the voltage in his glowing-wire tester. Several wires were burned up before the right voltage was found — giving enough brightness but not breaking the wire. He tested the ellipsoidal secondary with the hot wire close to the mirror and the knife edge at the long conjugate. Since this null test is sensitive to heat, I asked John about the heat from the hot wire, but he replied that it had not been a problem. This seems to be a very creative way to test a Gregorian secondary since the wire holders that conduct electricity can be made very tiny and will cause little obstruction.

Steve Rismiller had done a fine job on a 4" Schiefspiegler made from walnut and brass. Steve presented drawings of the light path and mount details so the viewer could better understand the optical design and mount construction. Jim McKinley displayed an 8" f/7.4 Newtonian mounted in a lightweight blue fiberglass tube. Machined pipe fittings made the mounting low-cost and very pleasant to use. John Kearns brought his 4.25" RFT he uses for astrophotography — the main feature of this telescope is a special adapter for his eyepiece that focuses at the precise place his camera focal plane is positioned. All John has to

do to take perfectly focused photos is to first insert the special eyepiece, focus, remove the eyepiece and mount his camera. John also displayed several nice astrophotos taken with his "Scotch" mount, which uses a large "clock" wheel for determining exact screw rotation during the exposure.

Brent Archinal displayed a 5″ f/15 refractor which he made, including the lens; and Doug Wereb had his 1881 4″ Alvan Clark refractor. Neither telescopes was entered in the judging. Doug also had a display entitled "Electronic Galaxy Spectra" and "Photographic Stellar Spectra."

The MVAS displayed its 16″ f/5.3 Newtonian on its large fork mount — and they claim that this telescope was built for less than $250! If your club is interested in how this was done, contact the MVAS. Three club members are responsible for the instrument: Ed Jones, Dick Hammer and John Graham.

Dick Suter brought a solar telescope with uncoated primary mirror and a couple of Herschel wedges, but skies were cloudy. A cautionary note: before building any solar telescope and looking at the Sun through it, be sure that it is safe.

After the opening address, given by Wade E. Allen of the MVAS, there were many interesting papers. The first two were by men from Ohio State University: "Spectroscopy At Lowell Observatory" by Doug Wereb and "Measuring Double Stars" by Brent Archinal. Then there was an excellent film on the planet Mars, and just before lunch, "Brightness of the Night Sky" by Loren Shumaker of the MVAS.

After lunch we saw another film, then held an informal round table discussion on amateur telescope making that was chaired by John Graham. John described a push-pull mirror cell for large mirrors, and how to make a body cap into a camera adapter. The round-table discussion seemed to turn on how to motivate club members to participate in club activities, and what sort of activity makes an astronomy club tick. A break seemed welcome before John Kearns' provocative paper, "Why Make a Small RFT?"

The closing address, "The Impact of Technology on Amateur Astronomy," was given by Dr. R. Kent Honeycutt, Indiana State University. Dr. Honeycutt critiqued the technologies related to astronomy, citing examples from amateur astronomy publications which form much of the communications network between amateurs. Some of the areas touched by advancing technology lie within the realm of amateur astronomy.

It is not hard, for example, to imagine a computer-assisted polishing machine. It could be programmed to change the figure by polishing more on the high zones and less in the low areas. And why not have a lens in your Foucault tester behind which two detectors, one for each side of the mirror, tell the computer when the light level is the same for both? It would work like the Couder mask testing, but be quantitatively accurate.

Telescopes can use nearly any type of drive if furnished with a tachometer and electronic feedback to turn at the sideral rate. The merits of photography, a great way to record and store data, were compared to what the human eye can do — despite its shortcomings. Also, the technology has advanced in the film area, providing better hypersensitizing methods.

The future appears bright. Research now being done with thin mirror blanks will certainly bring down the cost and weight of large reflectors.

"What can the amateur do that is useful in astronomy?" asked Dr. Honeycutt. He suggested measuring double star separations using a filar micrometer — but challenged us to find a better technique or a better instrument.

The last, and probably the most fun, part of the program is the presentation of the awards and door prizes, and most of us were still present to collect if we were fortunate enough to win. Although the total registration was only 152, somewhat down from previous years possibly due to the lagging economy, this year's Apollo Rendezvous was well worth attending.

Richard J. Wessling
5429 Overlook Drive
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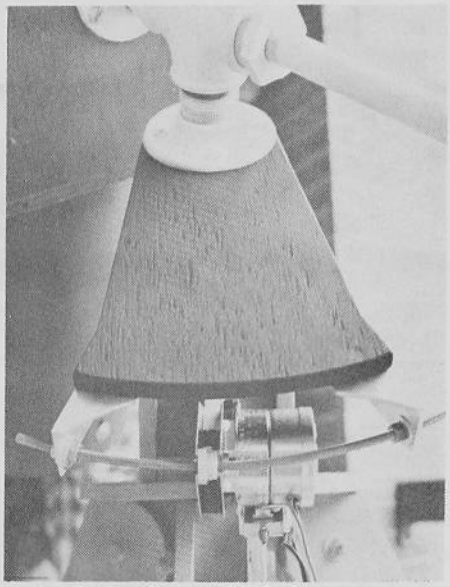
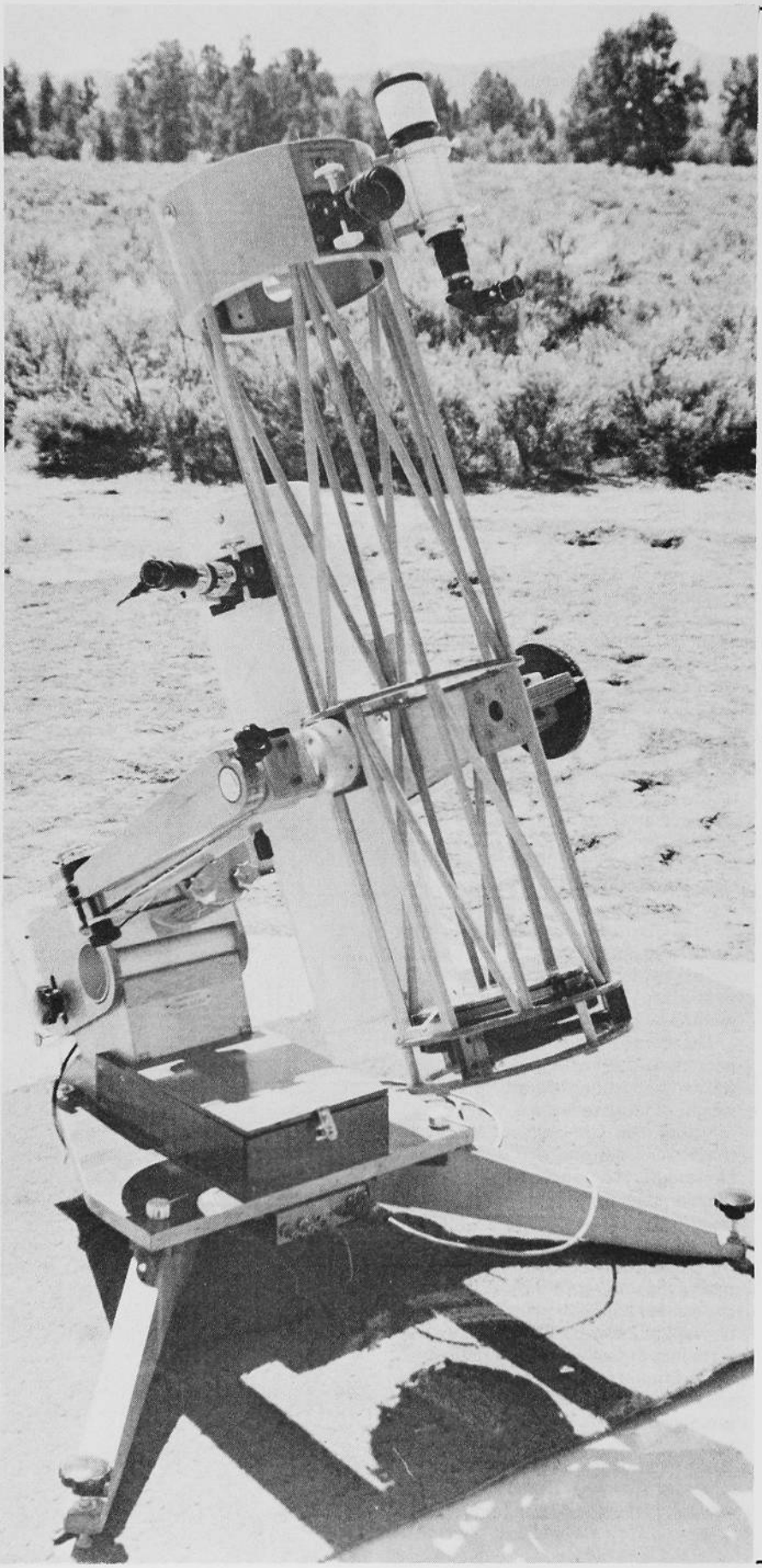


John Graham's curved bolt drive.

Jim McKinley +8″ reflector.
Dr. Honeycutt speaking.



Constructing:

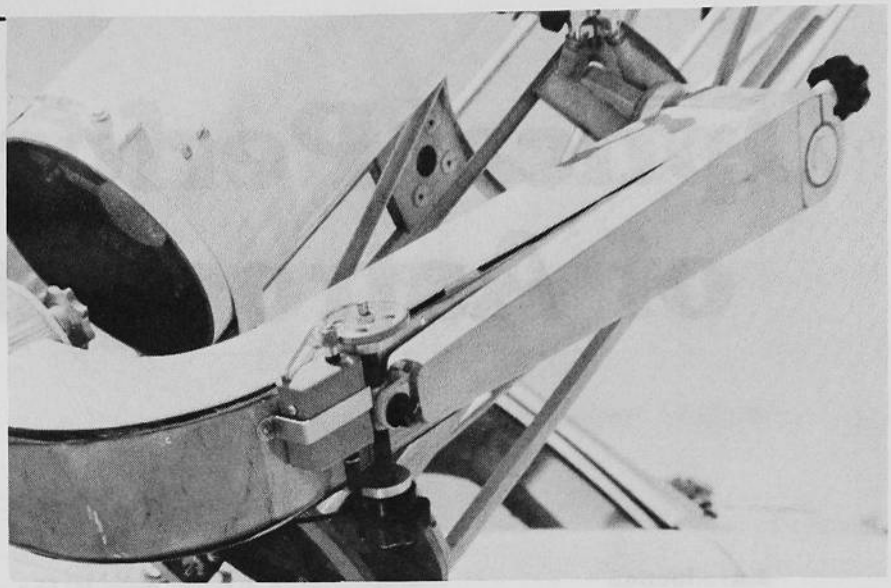
Upon completion of my 3″ wood-mounted telescope, I knew I needed a larger instrument. The new instrument had to be transportable in the family car and be constructed from easy-to-work and readily-available material with simple hand tools. Much thought went into the choice of size and material: a 4″ or 6″ didn't seem to be large enough, but a 10″ was probably a little too much for a portable second telescope project. The choice was an 8″ Newtonian.

At the Riverside Telescope Makers Convention last May, I purchased an 8″ f/6 mirror, mirror cell, and spider. I also took lots of pictures, looked at all the telescopes and questioned many owners. One way to make a telescope more portable is to make it light — and one way to make it light is to get rid of the counterweights. The fork mount combines these attributes — so a fork it was. I was sure a structure wouldn't have to be massive to be stiff, so my material choices were birch aircraft plywood, plus oak and spruce, properly oriented, for stiffness and low weight. I used teak and mahogany for trim.

The first item to be started was the fork, built on a subframe of ½″ by ½″ spruce with a base plate of 1″ oak and skinned with three layers of 1/16″ aircraft plywood. I staggered the edges for greater corner strength.

The base was constructed from scrap 1″ lumber overlayed with 3/16″ teak. The mount for the polar shaft housing is built up from two layers of ¼″ aircraft plywood screwed and glued to the base. I added a mahogany accessory box for

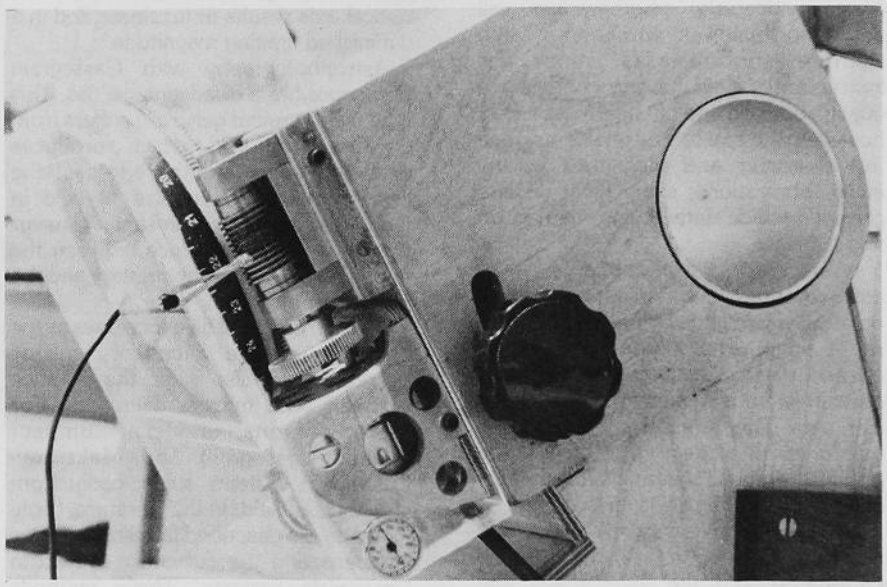
the "Wooden Wonder"



convenience and stiffness to the platform assembly. The legs are ⅛" and ¼" aircraft plywood over a mahogany and oak frame, bolted to the platform. The two front legs can be pivoted back for easy storage. Each leg has an adjusting foot for fine polar alignment.

A tiltable polar axis housing was built up of ¼" plywood to a thickness of ½". An aluminum tube 1.870" I.D. serves as the polar axis bushing. For the polar shaft, I turned a piece of galvanized pipe to 1.865" O.D. and had it nickle-plated. Silicone grease lubricates this bearing.

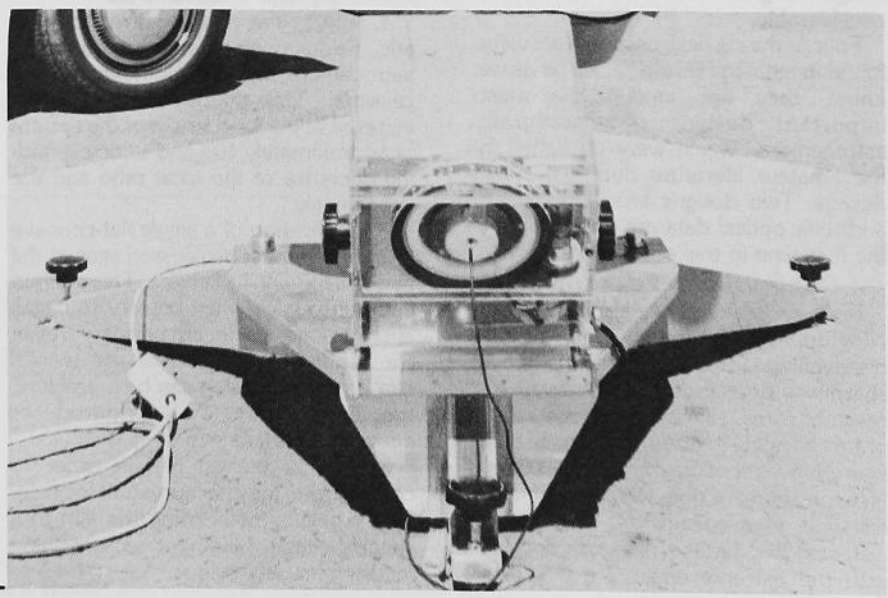
The open-frame tube was constructed from ⅜" plywood rings and ½" wood dowel. The tube is suspended between oak bearing blocks with Delrin bushings. The declination shafts were turned from aluminum bar. The 2" focuser is from Meade; I shortened it because it was too tall.



The finish on all wooden parts is two coats of hand-sanded marine spar varnish.

For a drive, I worked out a circuit for a dual axis drive corrector, bought the parts at a local electronics house, and assembled it myself. The hand controller is made from sheet styrene. The final touch is a 6" Byers worm gear drive with Hurst reversible synchronous motor. I machined the Delrin clutch and right ascension setting circle and they are attached to the drive gear. A pointer attached to the end of the polar shaft allows direct star indexing.

Tom Greska
Lawndale, CA
■



Optical Performance of Astrocameras

Introduction

Sooner or later every experienced amateur deep-sky photographer will desire to build or purchase a large aperture astrocamera. Of course, this instrument should have a good image quality, both on and off-axis. Most times, however, the amateur is unable to judge the character and magnitude of the image aberrations, since most dealers cannot provide detailed information on this subject.

In this article, we discuss six types of astrocameras and investigate their optical performance by means of optical ray tracing. The instruments are all catadioptric Cassegrain systems containing both refracting and reflecting elements. They are designed in such a way that the image lies behind the primary mirror so that an SLR camera, a 6x6cm camera, or a film cassette can be used. We have chosen the same aperture, 200mm, for all the systems considered, but the focal ratios and image angles they provide differ considerably.

Four of the six designs discussed were found in amateur literature. As far as we know, they are among the most important designs of Cassegrain astrocameras which were published in the amateur literature during the last decade. Two designs are very recent, and their optical data are presented for the first time in this article.

Conventional Telescopes

Most deep-sky photographers use a Newtonian telescope. One of its disadvantages is that the off-axis image sharpness decreases considerably as a result of coma, especially for focal ratios of f/6 or faster. In order to illustrate this, figure 1 gives spot diagrams for a 200mm Newtonian telescope with the off-axis distance as a parameter. The largest distance, 37.5mm, corresponds roughly with the extreme edge of a 6 x 6cm negative which, in reality, measures 55 x 55mm. The spread of light outside the optical axis results in fuzziness and in a diminished limiting magnitude.

Astrophotography with Cassegrain telescopes has a disadvantage, too. This type of instrument generally suffers from curvature of field which produces unsharpness toward the edges of the field. Significant curvature of field in Cassegrain systems is present whenever there is a large difference between the radii of curvature of the primary and the secondary mirrors.

This curvature of field increases as the diameter of the secondary mirror decreases and also when the distance between both mirrors decreases. For these reasons, modern compact Schmidt-Cassegrain and Maksutov-Cassegrain systems suffer badly from curvature of field. In the literature, three methods are described for eliminating or compensating the curvature of field in Cassegrain systems. These methods each have their disadvantages:

1. Application of a negative, achromatic field-flattening lens between the astrocamera and the photocamera or cassette. This method results in an increase of the focal length of the system of approximately 40% and a corresponding decrease of the focal ratio and the image angle.

2. Application of a single flat-concave lens, which must be pressed against the film surface with its flat side. This method causes troubles when you try to install such a lens inside an ordinary reflex camera. In practice, it forces the use of a film holder. Focusing can be a problem, too. Furthermore, the lens introduces coma and astigmatism of its own.

3. Use of curved film in order to compensate for the curvature of field. The problems of bending the film to a specific shape, holding it securely, and focusing are all obvious.

The Astrocameras

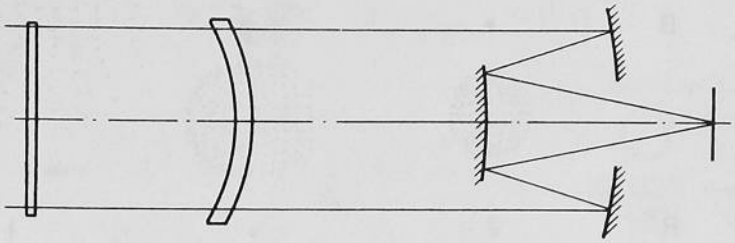
The six astrocameras we will consider have either fully or partially eliminated these problems. All have a flat or nearly flat focal field, usually by reducing the difference between the radii of curvature of the primary and the secondary mirrors. This, however, always leads to an increase of the diameter of the secondary mirror. In some instances, it reaches 60% of the diameter of the entrance pupil. These instruments, therefore, can hardly be used for visual observations.

The six systems are shown in figure 2, all drawn to the same scale and arranged from top to bottom according to decreasing focal ratio. The indicated "geometric focal ratios" do not include the loss of light caused by the central obstruction.

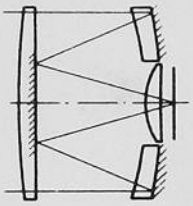
All these systems have a spherical primary mirror, and spherical aberration is suppressed by one or more corrector elements. In the Astrostar, this function is accomplished mainly by the Mangin mirror, a mirror consisting of a reflecting and a refracting element. The color aberration caused by the refracting part is eliminated by the other two lenses. The Mangin mirror principle is often used in mirror telephoto lenses.

The Companar, Simak, and Sigler Maksutovs all belong to the family of meniscus mirror systems, and are all derived from the famous Gregory-Maksutov design. This instrument, consisting of a spherical primary and a meniscus corrector with an aluminized spot on its back, has become very popular among amateurs since the 50s. Ray tracing analysis shows, however, that the focal ratio of this instrument is limited to about f/10 because of color and other off-axis aberrations, especially curvature of field.

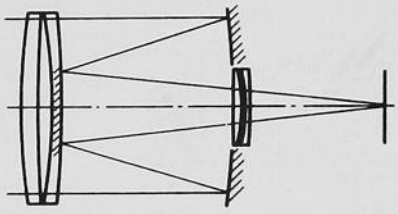
This restriction can be diminished by separating the secondary mirror from



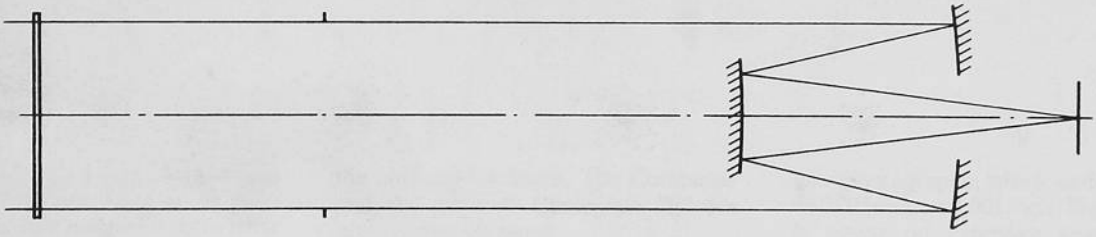
Companar f/2.5



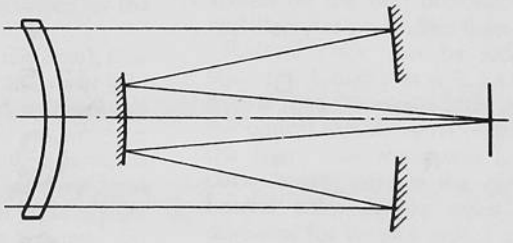
Astrostar f/1.25



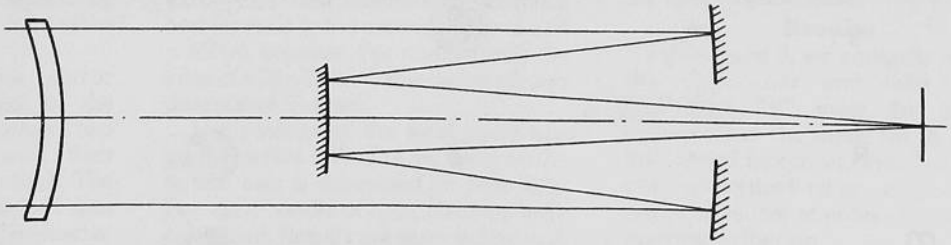
Heliotar II f/3



Schmidt Cassegrain 'R' f/4



Simak f/5.6



Sigler Maksutov f/8

Fig. 2

Sigler
Maksutov
f/8
Simak
f/5.6
Schmidt
Cassegrain
'R' f/4
Heliotar II
f/3
Companar
f/2.5
Astrostar
f/1.25
R
B
V
0
12.5
25
37.5
> 0.15
Scale
0.025 mm

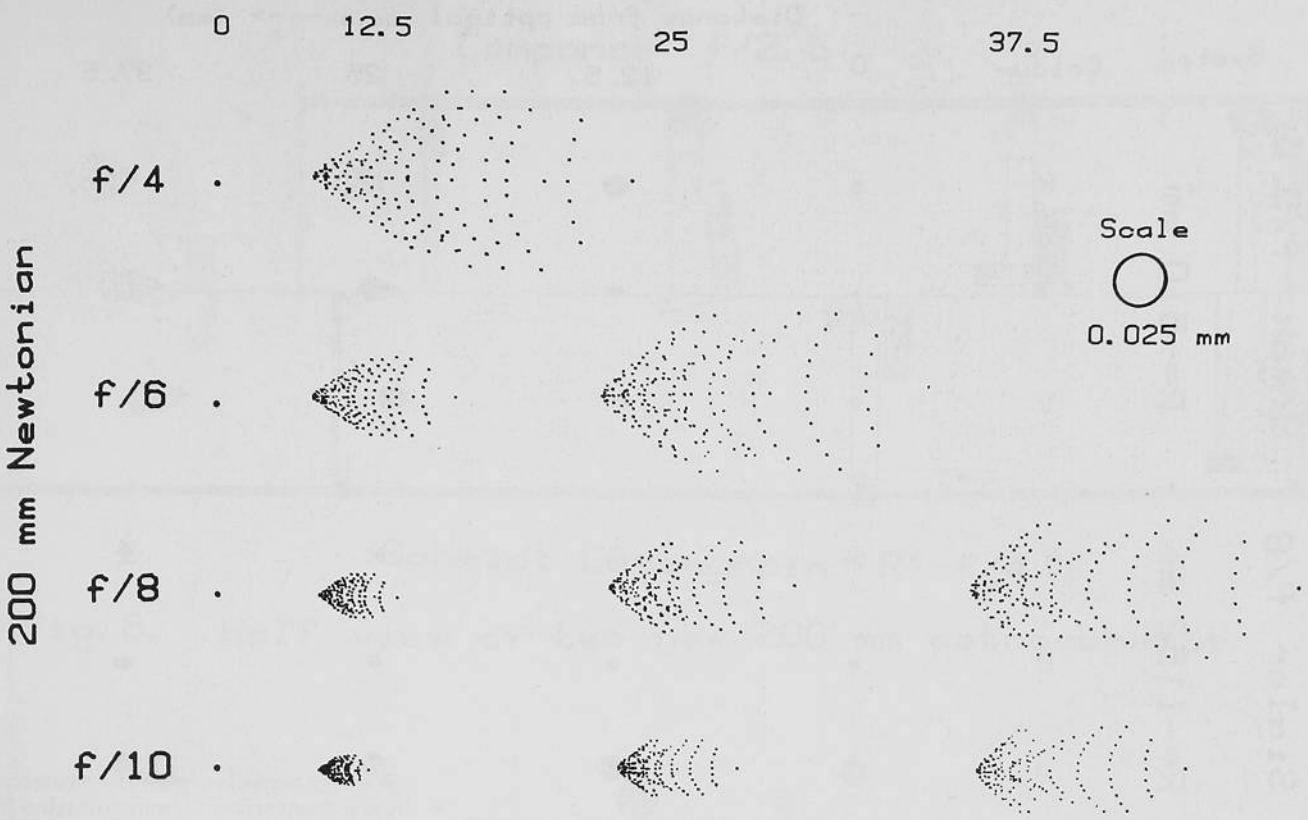


Fig. 3 (left) and Fig. 1 (above) show spot diagrams for the six cameras in three wavelengths of light compared at the same scale to a group of 200 mm Newtonian reflectors.

the meniscus corrector and simultaneously giving this mirror another radius of curvature than the back side of the meniscus. These principles are applied in the Simak and Sigler Maksutovs. This type of system has its restrictions as well: for f/ratios shorter than about f/4, the color aberration of the meniscus becomes intolerable. The designer of the Companar suppressed the color aberration of his meniscus system by placing a weak positive lens in front of the corrector.

Quite different meniscus mirror system design is embodied in the Heliotar II. This instrument contains two meniscus lenses placed with their concave sides facing each other. The secondary mirror is an aluminized spot on the back side of the second meniscus.

The Schmidt Cassegrain "R" has two spherical mirrors with nearly equal radii of curvature. The Schmidt plate is located near the center of curvature of the primary mirror.

Four of these six designs were found in the amateur literature. The Companar and the Schmidt Cassegrain "R" are quite recent designs.

Optical Ray Tracing

Based on the optical data given in table 2, spot diagrams were calculated for the following parameters:

- For red light (lambda = 656.3nm), blue light (lambda = 486.1nm) and violet light (lambda = 404.7nm). Red is important particularly for photographing emission nebulae, since their light is emitted mainly in H-alpha. Galaxies and relatively young stars emit most of their light in the blue and violet regions.
- On the optical axis and at distances of 12.5, 25 and 37.5mm from the optical axis. The last mentioned distance corresponds to the extreme edge of a 55 x 55mm negative. For comparison, the edge of a 24 x 36mm frame has an off-axis distance of 21.6mm.

The position of the focal plane was chosen so the spread of the spots on the optical axis is minimized for blue light. For each bundle of rays, 200 rays were calculated. Results are given in figures 3, 4 and 5. Spot diagrams larger than 0.15mm are not included because of their large size.

The spot diagrams for the three colors are to be compared with a maximum allowable spread criterion for astrophotography, which we have taken as 0.025mm, or 0.001 inch. This criterion is based on extensive investigations (published in ref. 3), in which it appeared that the smallest diameters of star images on the best professional photo negatives are no smaller than 0.025mm.

Lateral color can be judged from figures 3, 4, and 5 as well. Lateral color means that the image scale away from the optical axis depends on the color of the light. This aberration appears as color fringes outside the optical axis. Lateral color occurs when the spot diagrams for various colors are shown shifted with respect to each other. These shifts were drawn on the same scale as the spot diagram itself.

Results

From figure 3, we conclude that only the Companar and the Schmidt Cassegrain "R" meet the 0.025mm criterion over the whole flat 55 x 55mm frame; and moreover, they hold lateral color within this limit as well. We will pay some additional attention to these two systems further on.

A close look at the Simak and Sigler Maksutovs reveals that the swelling of the spot diagrams at some distance from the optical axis is a result of field curvature. While the image sharpness on the curved focal plane appears to meet

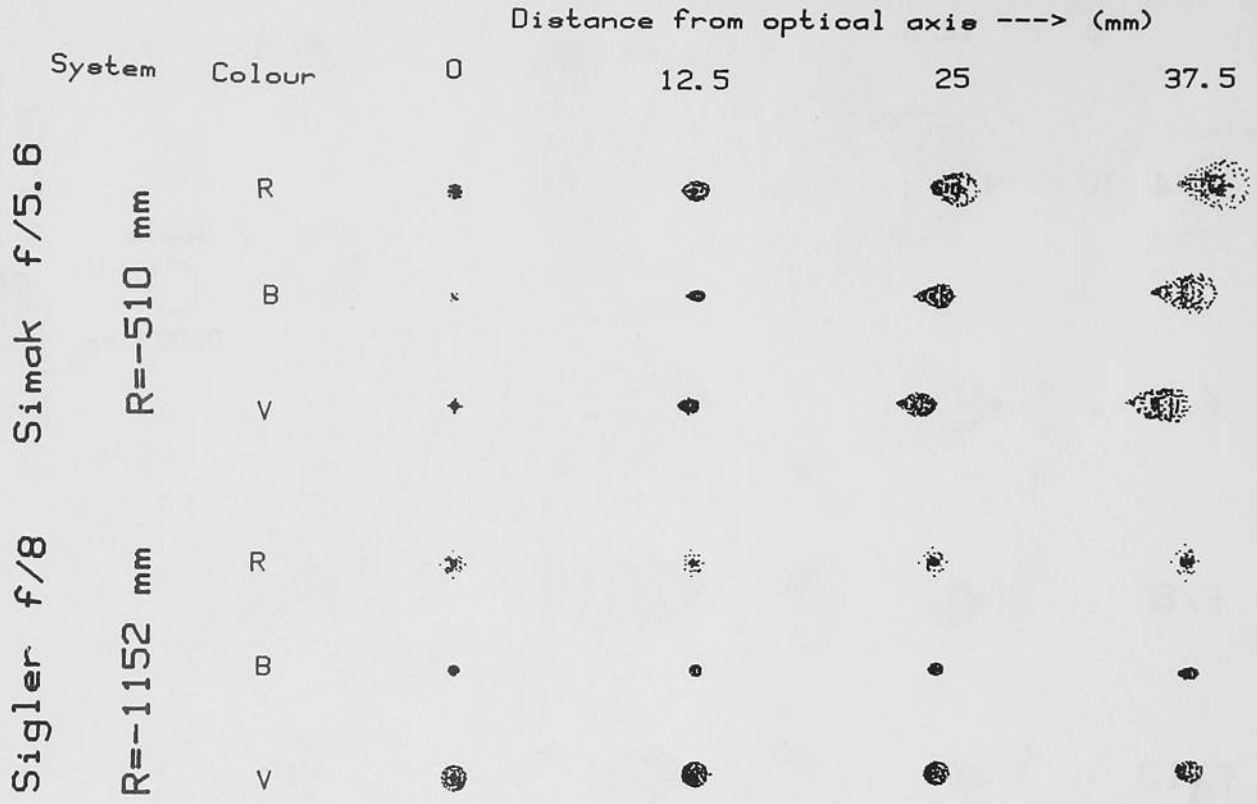
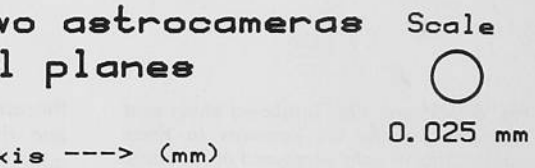


Fig. 4. Spot diagrams for two astrocameras for the curved focal planes



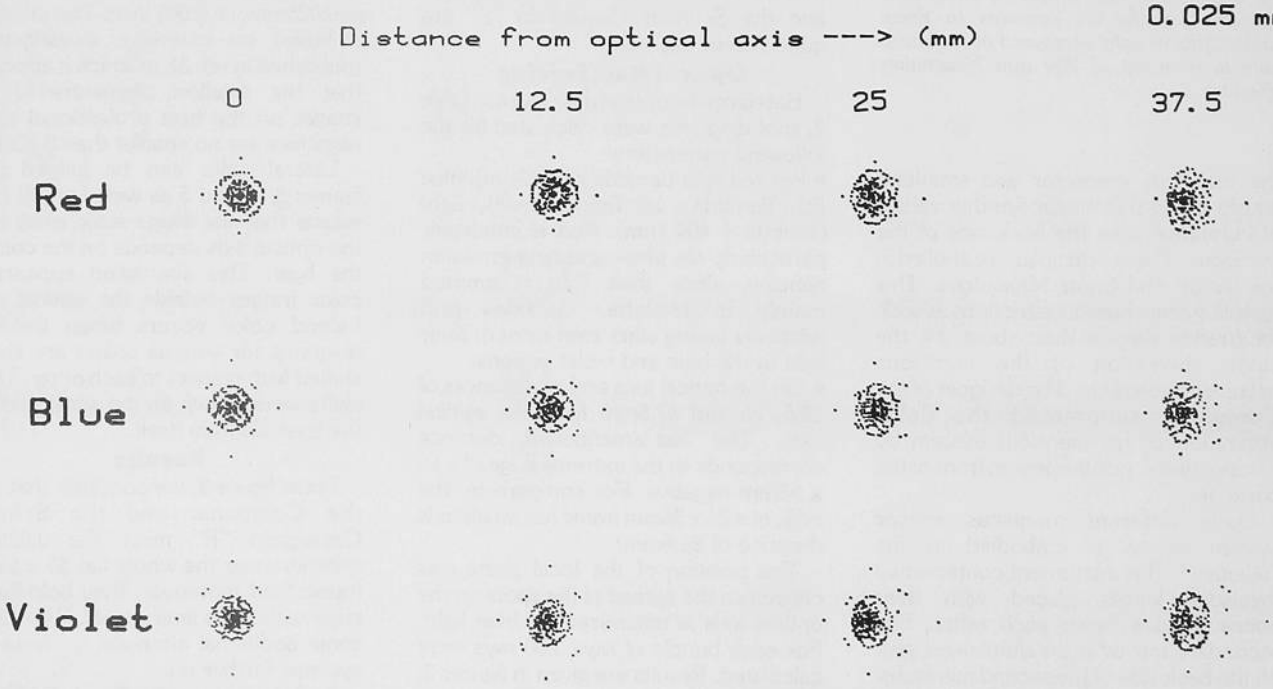


Fig. 5. Spot diagrams for the spherical COMPANAR for the flat focal plane

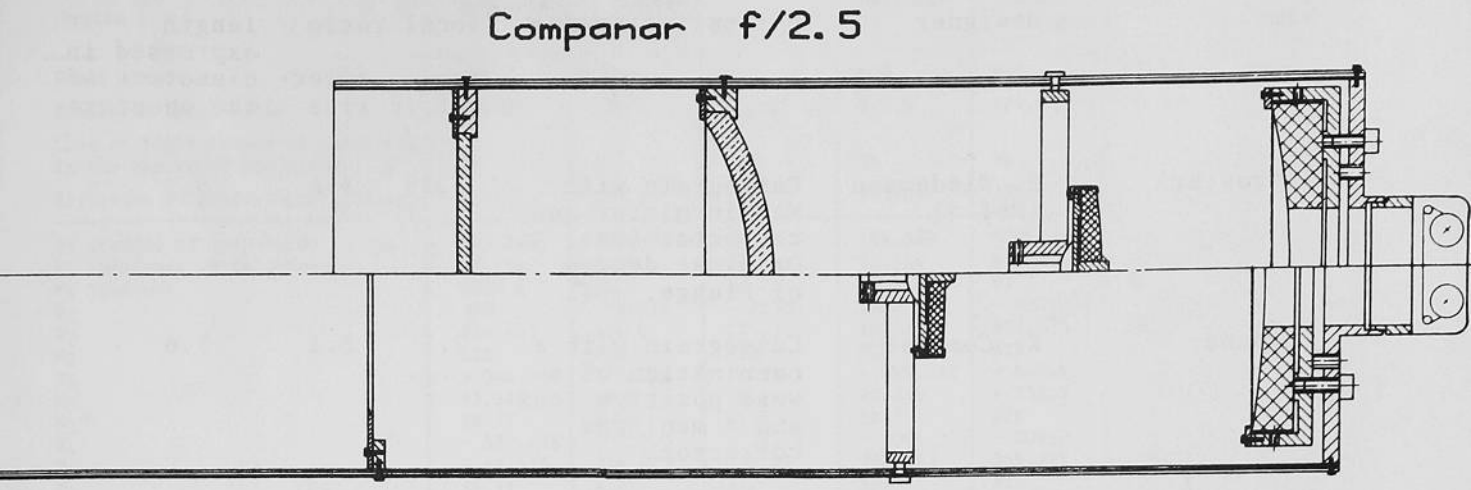


Fig. 6. Half view of two new 200 mm astrocameras

roughly the 0.025mm criterion (figure 4), in order to realize this image sharpness in practice, you would need curved film or a field flattener. Moreover, the Simak has lateral color toward the edge of the field; note how the spot diagrams for red, blue and violet light are shifted with respect to each other.

It should be noted that if these systems do not all meet the above mentioned criterion over their whole field, they can be quite satisfactory for a smaller field, or for a limited wave length. The last applies particularly when the instrument is used with films having a selective spectral sensitivity or with colored filters.

Two Recent Designs

Because of the excellent optical quality of the Companar and the Schmidt-Cassegrain "R," let's focus our attention now on these two types of astrocamera.

The designer of the Companar placed a weak convex spheric lens in front of the meniscus in the center of the curvature of this meniscus to eliminate the residual spherical aberration of the system. A spherical design has a spread on the optical axis of 0.03mm. Aspherizing this lens would not be necessary if the focal ratio of the system did not exceed f/2.85, as is shown in figure 5; all optical surfaces would then be spherical. The primary mirror of the Companar must have a considerably larger diameter than the corrector and the meniscus to prevent excessive vignetting.

The Schmidt Cassegrain "R" is an optimization of a system originally proposed by Slevogt (ref. 6). The essence of this design is two spherical

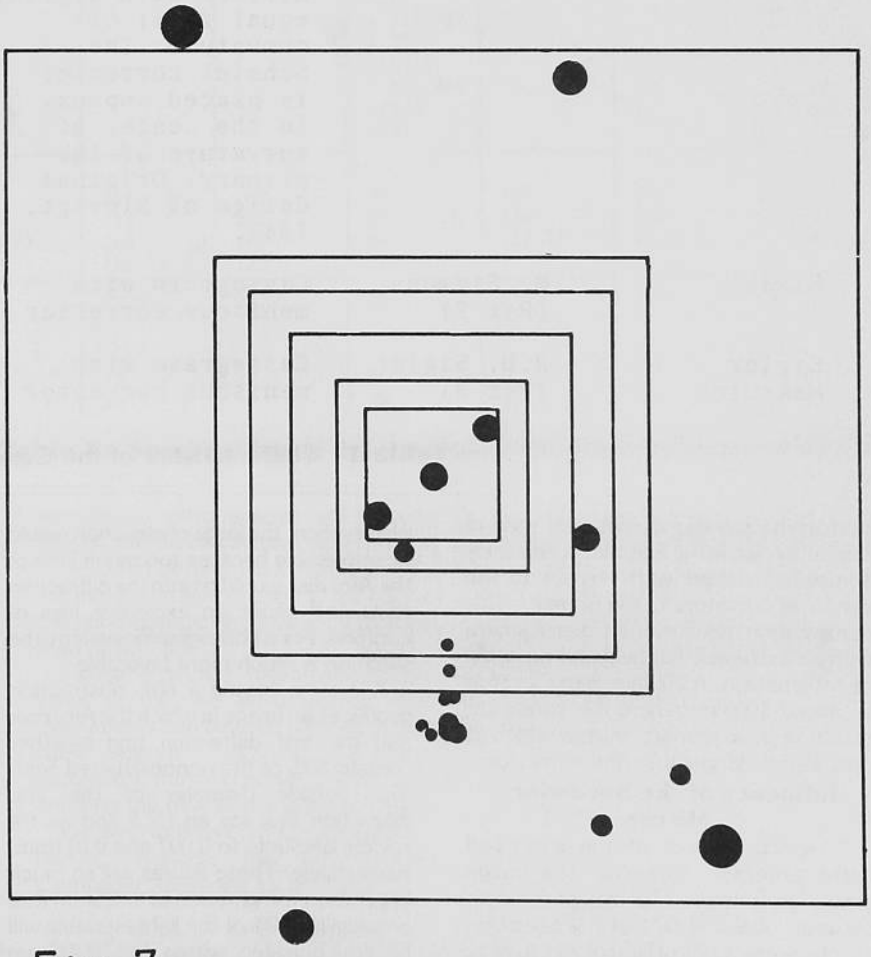


Fig. 7. The image size of the six 200 mm astrocameras for a 6x6 frame

Name	Designer	Optical principle	focal ratio		length expressed in diameters of the aperture
			geo-metric	effec-tive	
Astrostar	E. Wiedemann (Ref 4)	Cassegrain with Mangin mirror and corrector lens. Original design of Flugge, 1941	1.25	1.6	0.9
Companar	K. Compaan	Cassegrain with a combination of a weak positive lens and a meniscus corrector	2.5	3.1	3.6
Heliotar II	E. Wiedemann (Ref 5)	Cassegrain with two meniscus corrections. Original design of Mandler, 1955	3	3.8	2
Schmidt-Cassegrain 'R'	H.G.J. Rutten (Ref 6)	Schmidt Cassegrain with two spherical mirrors with approx. equal radii of curvature. The Schmidt corrector is placed approx. in the center of curvature of the primary. Original design of Slevogt, 1942.	4	5.0	5.5
Simak	M. Simmons (Ref 7)	Cassegrain with meniscus corrector	5.6	6.4	2.5
Sigler Maksutov	R.D. Sigler (Ref 8)	Cassegrain with meniscus corrector	8.0	9.2	4.7

Table 1 Characteristics of the Cameras

mirrors having slightly different radii of curvature, while the Schmidt corrector is somewhat shifted with respect to the center of curvature of the primary. This combination results in an astrocamera with an extremely flat field and no coma or astigmatism. A 200mm diameter stop is placed 300mm behind the corrector, resulting in a primary mirror which is only slightly larger than the corrector.

Influence of the Secondary Mirror

A special aspect of the described astrocameras concerns the large secondary mirror. The diameter varies between 50% and 60% of the aperture, which means a loss of light of 25% to 36%. The effective focal ratio is therefore 10% to 20% larger than the geometric focal ratio.

In a system designed for visual observation, the large obstruction would be intolerable because too much light of the Airy disk would go into the diffraction rings and cause an excessive loss of contrast. For a photographic system, the situation is much more favorable.

A system having a 60% obstruction produces an image in which the Airy disk and the first diffraction ring together contain 80% of the nonobstructed light. The outside diameter of the first diffraction ring for an f/2.5 and an f/4 system amounts to 0.007 and 0.011mm, respectively. These figures are so much lower than the criterion of 0.025mm that practically 100% of the light available will be concentrated within this 0.025mm circle. Thus, from a point of view of diffraction, a 60% obstruction is not detrimental to the photographic image sharpness of these two instruments.

We will be continuing this series of articles by Messrs. Rutter and van Venrooij with discussions of eyepieces, improved Schmidt-Cassegrain designs, and other topics we hope will prove to be interest to TM's readers.

In order to prevent vignetting of oblique bundles of rays on the extreme edge of the 55 x 55mm photo negative, some designs require larger secondary mirrors than specified in table 2. By

System	Astrostar	Companar		Heliotar II	Schmidt Cassegrain "R"	Simak	Sigler Maksutov
		aspheric	spherical				
Focal length	250	504	572	600	800	1122	1595
Geometric focal ratio	f/1.25	f/2.5	f/2.85	f/3.0	f/4.0	f/5.6	f/8.0
Loss of light caused by secondary in the centre of the field %	36	36	36	36	36	21	30
Effective (= photographic) fratio	f/1.6	f/3.1	f/3.56	f/3.8	f/5.0	f/6.4	f/9.2
R_1 (radius of curvature) mm	847.213	11070[4]	12300	704.568	∞	- 217.465[5]	- 297.709
D_1 (Distance or thickness)	18.116	10.0	11.1	17.754	6.0	19.425	20.60
M_1 (medium)	SSKN 8	BK 7	BK 7	BK 7	BK 7	BK 7	BK 7
R_2	∞	- 11070	- 12300	1657.576	- 83250[2]	- 229.025	- 309.455
D_2	116.461	210.0	233.3	15.217	977.2[3]	355.575	693.582
M_2	AIR	AIR	AIR	AIR	AIR	AIR	AIR
R_3	- 344.207	- 210.0	- 233.3	- 568.342	- 845.6	- 847.2	- 1311.818
D_3	15.528	18.0	20.1	10.145	- 231.6	- 289.675	- 413.473
M_3	SK 11	BK 7	BK 7	BK 7	AIR	AIR	AIR
R_4	- 521.485	- 228.0	- 253.3	- 1061.208	- 809.7	- 451.75	- 847.091
D_4	- 15.528	388.175	439.88	182.463	358.285	388.222	631.75
M_4	SK 11	AIR	AIR	AIR	AIR	AIR	AIR
R_5	- 344.207	- 520.84	- 584.13	- 793.765			
D_5	- 116.461	- 140.0	- 155.56	- 182.463			
M_5	AIR	AIR	AIR	AIR			
R_6	∞	- 500.68	- 562.44	- 1061.208			
D_6	116.461	240.283	276.49	182.463			
M_6	AIR	AIR	AIR	AIR			
R_7	75.70			2263.861			
D_7	15.528			9.465			
M_7	SK 11			BK 7			
R_8	1035.207			- 178.548			
D_8	14.28			3.626			
M_8	AIR			AIR			
R_9				- 167.792			
D_9				4.303			
M_9				SSKN 8			
R_{10}				- 524.888			
D_{10}				142.0			
M_{10}				AIR			
Diameters of the optical elements							
d_1	201	201	201	201	216	208	206
d_2	198	213	213	201	236	236	242
d_3	120 [1]	240	240	208	120 [1]	96 [1]	112 [1]
d_4	80	120 [1]	120[1]	120 [1]			
Diameter field free of vignetting	22	27.5	24	25	44	75	75
Light drop-off as a result of mm vignetting:							
- corner 24x36 mm negative, %	13	13	13	6	0	0	0
- corner 55x55 mm negative, %	39	36	36	22	22	0	0

Table 2 Specifications of the Cameras

Notes on Table 2:

1) **Diameter secondary mirror**
2) **Schmidt plate, relative power 51%. Diameter of neutral zone 173 mm.**
3) **At a distance of 300 mm from the Schmidt corrector a stop with a diameter of 200 mm is placed.**
4) **Aspheric. Deformation ¼ wave length.**
5) **Aspheric. Deformation ¼ wave length.**

restricting the maximum diameter of the secondary mirror to 120mm, some light dropoff occurs at the edge of the field.

Table 2 gives the diameters for the image field that is free of vignetting for each of the astrocameras and the light dropoff for the 24 x 36mm corner and the 55 x 55mm corner. As a rule of thumb, the maximum light dropoff at the edge of the photographic negative should be less than 30%.

Figure 6 shows half-cross-sectional views of the two astrocameras. Both instruments can be used without a baffle tube system because the large secondary mirrors prevent stray light entering the hole in the primary mirror.

We wish to thank Dr. K. Compaan for making available the data of the Companar, designed by him.

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2. *Sky and Telescope*, March 1957, page 236, John Gregory.
3. *La Construction du Telescope d'amateur*, Jean Texerau, page 269.
4. *Sterne and Weltraum*, 1978-8, E. Wiedemann.
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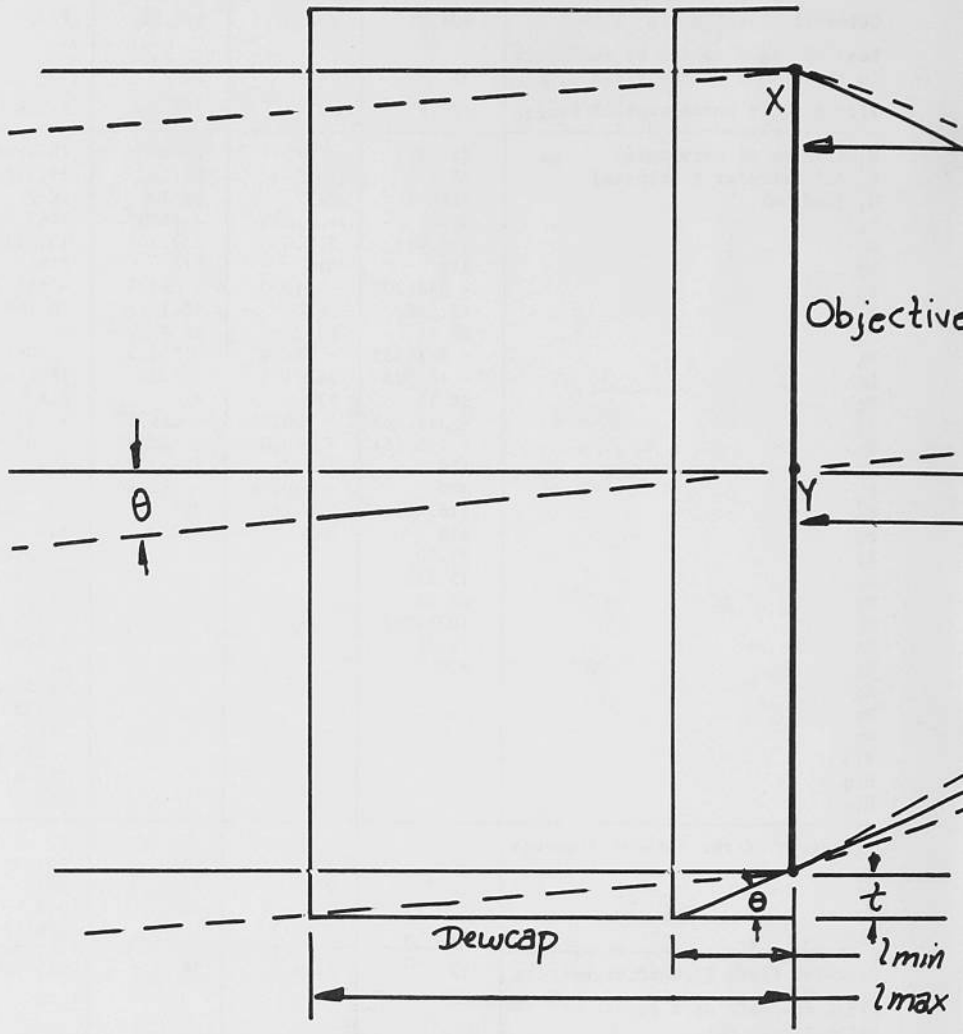


Too little has been written recently on determining the size of diagonal mirrors in Newtonian telescopes, and nothing at all on draw tube and dew cap diameters and lengths in refractors. These problems are very closely related, though, and a general solution that can solve them exists. Instead of relying on manufacturers' recommendations or equations of unknown origin, TMs can use the equations developed below to compute many different values. Equations are given in a BASIC-like form to aid program writing.

We start by determining the diameter of the area of full illumination, a. The radius for full illumination is:

$$a/2 = F \times \tan(\theta) \qquad \text{(eqn. 1)}$$

where F is the focal length of the telescope and θ is the desired angular radius of the field of view. In the initial design of a telescope, θ is chosen by the builder. For a telescope already built, θ is not immediately available and can be calculated using the auxiliary variables g and h:

$$\tan(\theta) = g/h$$

We define:

$$h = F - L$$

where L is the distance from the center of the diagonal or the end of the draw tube to the focal plane (see the diagram).

The value of g is trickier to find. The triangles XYZ and UVZ are similar, so we can say of the sides:

$$\overline{XY}/\overline{XZ} = \overline{UV}/\overline{VZ}$$

or:

$$(1/2) \times D/F = \overline{UV}/L$$

where D is the telescope diameter. We then find:

$$\overline{UV} = (L \times D)/(2 \times F)$$

The length g is the difference:

$$g = K/2 - \overline{UV}$$

This can be rewritten:

$$g = K/2 - (L \times D)/(2 \times F)$$
$$= (K \times F - L \times D)/(2 \times F)$$

where K is either the minor axis of the diagonal mirror or the diameter of the draw tube. We now find the following useful relation:

$$\tan(\theta) = g/h = (K \times F - L \times D)/(2 \times F \times (F - L)) \qquad \text{(eqn. 2)}$$

Using equation 2 in equation 1, we see that the radius of full illumination becomes:

$$a/2 = F \times (K \times F - L \times D)/(2 \times F \times (F - L)) \qquad \text{(eqn. 3)}$$

The diameter of full illumination is found by rearranging equation 3:

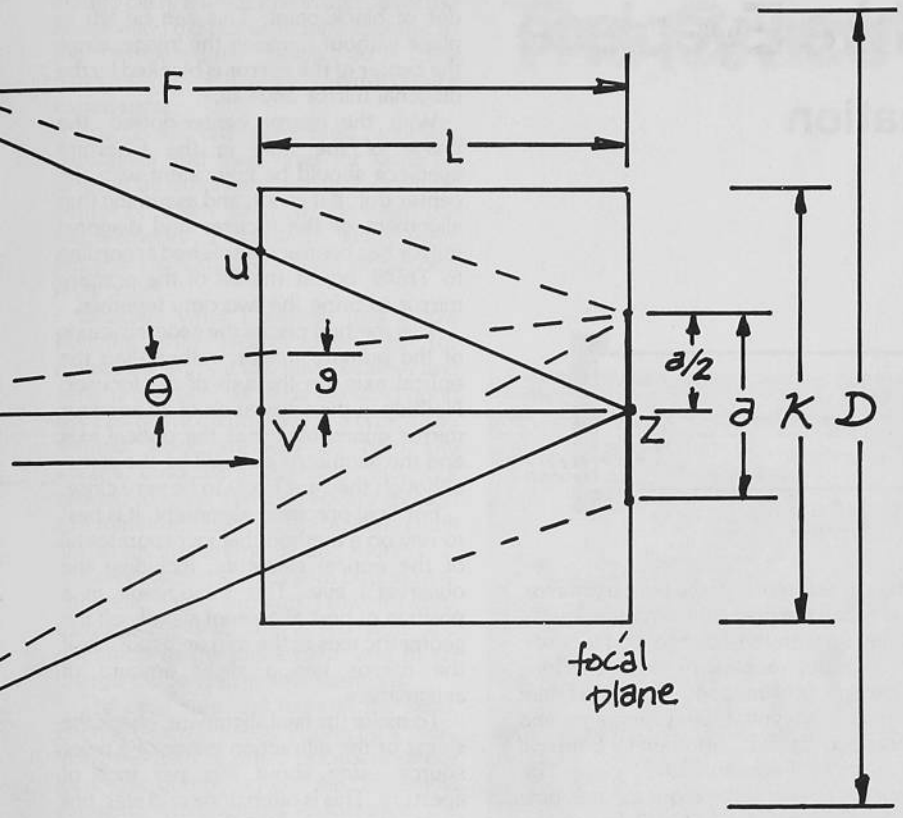
$$a = (F \times K - L \times D)/(F - L) \qquad \text{(eqn. 4)}$$

This may be rewritten to yield:

$$L = F \times (a - K)/(a - D) \qquad \text{(eqn. 5)}$$

and:

$$K = (a \times (F - L) + L \times D)/F \qquad \text{(eqn. 6)}$$



How To Determine the Size of: Diagonals Draw Tubes & Dew Caps

depending on which of these pieces of hardware can be altered to produce the desired diameter of the fully illuminated field.

Angle θ determines the maximum length of a Newtonian telescope tube or of any dew cap desired. If t is one-half of the difference of the inner diameter of the dew cap and clear aperture of the telescope (i.e., the clearance of the light path), then the length of the dew cap must not exceed length Lmax:

$$Lmax = t/\tan(\theta) \qquad \text{(eqn. 7)}$$

By rewriting equation 2 and substituting it into equation 7, we find:

$$Lmax = (2\times t\times F\times(F - L))/(K\times F - L\times D) \qquad \text{(eqn. 8)}$$

The minimum usable dew cap length, Lmin, may be defined with the equation:

$$Lmin = t/\tan(\phi) \qquad \text{(eqn. 9)}$$

where:

$$\tan(\phi) = (a/2 + D/2)/F \qquad \text{(eqn. 10)}$$

Substituting equation 10 into equation 9 and rewriting gives:

$$Lmin = 2\times t\times F/(a + D) \qquad \text{(eqn. 11)}$$

Using these formulas, the ATM can be assured of a workable design free of vignetting. The availability of hand calculators and home computers allows easy manipulation of all the variables until the optimum design has been found.

In summary, then,
Diameter of full illumination:

$$a = (F\times K - L\times D)/(F - L)$$

Distance of center of diagonal or draw tube end to focal plane:

$$L = F\times(a - K)/(a - D)$$

Minor axis of the diagonal or draw tube diameter:

$$K = (a\times(F - L) + L\times D)/F$$

Maximum dew cap length:

$$Lmax = 2\times t\times F\times(F - L)/(K\times F - L\times D)$$

"Minimum" dew cap length:

$$Lmin = 2\times t\times F/(a + D)$$

given:
D = telescope diameter
L = distance from focal plane to center of diagonal or end of drawtube
F = telescope focal length
t = ((I.D. of dew cap) - D)/2

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■

A Modified Cheshire Eyepiece

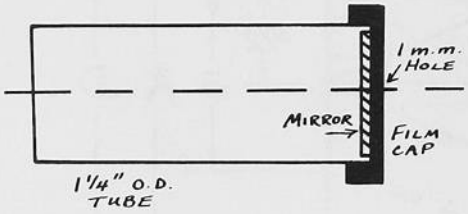
for Collimation

Alignment of the optical elements in a reflecting telescope is not well covered in telescope-making texts — in fact, the very lack of discussion might naturally lead novice TMs to conclude that compared to getting a good figure on the primary mirror, collimation contributes relatively little to telescope performance.

Moreover, the rough collimating techniques that are given, though satisfactory for a 6-inch f/8 Newtonian, simply aren't good enough for lining up an RFT or Cassegrain. I strongly suspect that many telescopes thought to have mediocre optics really need only proper collimation.

What has to be accomplished? The optical axis has to be directed through the exact center of the eyepiece by adjusting the position of the optical parts — if it is not, an off-axis portion of the image will be examined by the eyepiece. The quality of the image deteriorates quite rapidly away from the optical axis. In an f/8 Newtonian, the fall-off in image quality isn't too rapid, but in faster systems, say f/4, the area of good definition is much smaller and the fall-off more abrupt. For example, an f/8 Newtonian has a field only 0.358 inch in diameter within which coma is less than a ¼-wave error; an f/6 has a field of 0.151 inch, and an f/4 has a field only 0.045 inch in diameter. Clearly even for a slow mirror, the best part of the image is not very large, but for fast Newtonians and compound telescopes with fast primaries, it is vanishingly small.

A good method for collimating Newtonian telescopes appeared in TM #9, and was also presented in *Sky and Telescope*, December 1962, with a correction in February 1963. The method starts by making the eyepiece point squarely at the diagonal mirror, but not at the center of the diagonal, however — see the articles for details. Next, the diagonal is aligned so that it looks at the center of the primary mirror, and finally the primary mirror is adjusted to line up with the diagonal and focuser.



A useful accessory for checking telescope collimation is a Cheshire eyepiece, invented 50 years ago and described by B.L. Souther in *Sky and Telescope*, February 1978, page 175. Souther's eyepiece requires machine tools for fabrication, but I will describe an easy way to make a modified Cheshire eyepiece without access to machines.

Obtain a piece of 1.25" O.D. sink-trap tubing at a hardware store and a plastic cap from a Kodak 35mm film canister. From the canister cap, shave off the little bump that protrudes from the middle of the inside surface. Turn it over and punch a one millimeter hole in the exact center — a spot conveniently marked by a molding artifact.

Next, shape a piece of mirror from a cosmetic compact with a glass cutter and carborundum stone until it is circular and fits in the middle of the cap. Glue it to the inside surface of the cap, mirror face out, using silicon bathtub sealant. When the sealant has cured, scratch a one millimeter hole in the center of the reflective coating of the mirror by working through the hole in the cap with a sharply pointed tool.

Place the cap on a three-inch section of tubing and insert this assembly into the focuser. The mirror in the Cheshire eyepiece serves to reflect light from the inside of the telescope and allow the hole in the center of the end cap to be seen. It may be necessary to tilt the Cheshire mirror a slight amount if it reflects the diagonal mirror.

If the primary mirror has no center dot, cut a circular piece of heavy paper the same diameter as the mirror and place it on top of the mirror. If a compass was used to draw the circle, the compass hole marks the exact center. Mark the center of the mirror with a two millimeter dot of black paint. This can be left in place without harming the image, since the center of the mirror is blocked by the diagonal mirror anyway.

With the mirror center-dotted, the image of the hole in the Cheshire eyepiece should be coincident with the center dot. If it is not, and assuming that alignment of the focuser and diagonal mirror has been accomplished according to TM#9, adjust the tilt of the primary mirror to bring the two dots together.

This method places the geometric axis of the primary mirror, rather than the optical axis, on the axis of the focuser. Nothing in the fabrication of an amateur mirror guarantees that the optical axis and the geometric axis will be the same, although they are likely to be very close.

For final precision alignment, it is best to rely on a method that incorporates all of the optical elements, including the observer's eye. This may result in a position of best alignment slightly off the geometric axis of the mirror, especially if the mirror has a slight amount of astigmatism.

To make the final alignment, check the shape of the diffraction image of a point source using about 50x per inch of aperture. This is often done on a star, but I prefer an image of the Sun reflected on a power line insulator 500 or more feet away. The seeing has to be good, so this is best done on a calm day one or two hours before sunset. If the diffraction rings are even and concentric around the central disk, then alignment is perfect.

If not, adjust the tilt of the primary mirror to obtain this condition. Then insert the Cheshire eyepiece — if the two dots are superimposed, fine. If not, note the relative distance and direction separating them. Then, every time you use the telescope, check with the Cheshire eyepiece to be certain that the relative positions of the dots have not changed. With perfect alignment, axial star images will focus to crisp points and a telescope will give its best performance. Further information about evaluating the mirror from the diffraction image is found in *ATM, Book 1*, pages 428-436.

A telescope which will not hold alignment is a nuisance. If yours often needs realignment, consider the improvements to mirror mounts and diagonal holders suggested by Mr. Robert Cox in TM#6 and TM#7.

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■

The Grace Observatory

The time had come. There was no dodging the fact that I had to have a backyard observatory. I had progressed from a 3-inch reflector, through an RV-6 to the 13.1-inch Odyssey I. No longer could I carry a telescope in and out of the house and I did not want full exposure to the temperatures below 20°F that northwest Florida sometimes experiences.

So, I started searching articles, pamphlets and magazines for ideas on designs by other amateur astronomers. None of them seemed to meet the requirements I wanted. They went beyond my carpentry skills or beyond my budget.

Basically what I wanted was a low building that would open up for maximum sky, yet still have weather and wind protection, all while allowing good sky clearance on one side at a time. I also wanted work surfaces to hold sky atlases, binoculars, eyepiece, etc., but needed to keep the floor square footage to a minimum. Happily the building I built fills all my requirements and more.

Construction started with pouring a 4" concrete slab. I brought 110-volt wiring through the slab for a red light and operation of the clock drive and to re-charge my re-chargeable flashlight.

The next step was to build the walls. Each is approximately 7' long by 4' high. With the help of other members of our local astronomy club, the Escambia Amateur Astronomers Association, the work progressed quickly. We bolted the walls to the slab and attached each wall to the others at the corners with 90° angle brackets. I wanted the walls bolted and the roof hinged so that I could take the building apart and move it if my wife and I move from our current home. During the installation of the corner angle brackets, I glued residential door insulation into the corners to make them airtight and watertight.

Now for the roof — basically a frame of 2 x 4s cut in two to make 2 x 2s covered by ¼" plywood sheathing and galvanized tin for weather resistance. The roof has two sections. One section overlaps the other to prevent leaks. Gables were attached to the end of each roof section. The two half-roof sections are hinged so that they open 180° for full open, 90° to stand vertically as a windbreak, or can fold down to the closed position. Latching gate hooks hold the roof sections closed in the event of high winds.

The roof sections presented the first real problem. The panels were too heavy for me to lift from one end. I tried lifting from the inside and found this easy enough, but I could not manage to hold the weight in order to lower them to the 180° wide open position or to close them. To solve this, I installed an arm on the

support posts outside the building. These are hinged on the posts. Heavy ⅜" x 7" bolts passing through ½" copper sleeves in the arm and posts act as hinges, and protect the wood from wear and getting wobbly. They also allow me to lift the roof panels from the inside of the building to the point of rest on the raised arms. Then I go outside and let the roof panel down on the support posts to the horizontal position.

The arms are supported in the upright position by latching gate hooks. This is important in keeping the arms from slipping and letting the roof panels fall. Closing the building works just the reverse of opening it. Since the building can be opened and closed by one person without calling for help, my wife is much happier with it.

The weather panels for each end of the building became the next problem. I needed them so that in the winter I could raise three sides for wind protection leaving one end or side down for viewing.

I realized that I couldn't hinge them so that they would fold vertically inside the walls and still open up to the vertical position and then drop farther to a horizontal position for a work surface. To get the three positions, I installed ⅜" pins on the ends of each panel. These drop into ½" corner sleeves, drilled and inserted in the header plates of the end walls so that the panels can stand vertical. Hose clamps installed on the header plates accept the pins, and for a work surface, I lay the weather panels down horizontally.

The observatory is now complete and luckily has proven waterproof. All walls and room sections were insulated with 2" polystyrene to prevent excessive daytime heating of the building. The foam is painted flat black inside to prevent light reflection.

The roof sections and high end weather panels are a pleasant side benefit that I must admit I didn't fully foresee at the beginning of construction. When they are opened to the maximum horizontal position, they provide plenty of handy working surface for star atlas sheets, binoculars, note pads, ocular case, etc. — and I can have everything at my fingertips on any side of the building.

As an added convenience my wife made me a carpenter's apron with six pockets. I put this around my waist and put eyepieces each in a separate pocket, plus have the barlow lens, rechargeable flashlight, pencils, etc. at my fingertips.

Another convenience is an eyepatch with an elastic band. I use it to cover one eye while viewing to prevent fatigue from squinting eyelid muscles.

A word of advice to any future builders: avoid corrugated fiberglass for exterior walls. It is fragile, difficult to cut without breaking, impossible to make attractive corners with, difficult to seal, and it might not stand up to high winds. Use plywood. I will probably rip off the fiberglass panels on my observatory soon and replace it.

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■

You *Can* Take It with You!

(or Building a Prefab Observatory)

The ultimate dream of most amateur astronomers is to live where the skies are dark and clear and to have available, at a moment's notice, a large telescope in a back yard observatory. Few of us ever fulfill that dream — conditions are seldom so ideal. Lights of a nearby city or town may pollute the potentially dark skies. So we postpone that permanent installation until the happy night in the distant future when we will live on the crest of a dark rural hill.

These were my thoughts last summer — and yet I didn't want to wait. The solution became crystal clear — I'd build an observatory I can take with me when I move! It had to be small enough to move, or constructed in easily-handled sections which could be dismantled and reassembled with little expense or damage.

The second alternative seemed especially attractive since it would accommodate a large telescope, the complementary aspect of the amateur dream. And so it was that I started on the design and construction of a prefab observatory.

A Wish List

As long as I was dreaming, I decided to try to incorporate as many desirable features as possible:

- sturdy rotating dome
- spacious size — 12-foot diameter
- wide opening, with clear sweep from horizon to beyond the zenith
- no internal obstructions
- daytime skylight with shutters closed
- ability to open and close in two minutes
- weather-tight
- one-person construction
- buildable with small power tools
- uses common materials
- can be disassembled by one person in one day
- original site restorable by one person in one day at low cost
- managable sections easily transported
- re-erectable on new sight by one person in two weeks at low cost
- unique design
- attractive design
- cost under $1000

The reader will appreciate just how formidable a list this is — but happily the accompanying pictures and description relate my success on this ambitious project. I will not go into all the frequent mental anguish and false starts that ocurred before I finally arrived at a surprisingly optimized design.

Design Overview

Of the 500 hours I dedicated to this project, nearly 200 were spent at the drawing table. I visited local friends and observatories to collect as many good old ideas as possible, as well as many "don'ts" learned the hard way. I am indebted to them for their helpful suggestions and candid admissions of problems they have with their own observatories. Their experiences allowed me to achieve a uniquely functional facility. I dedicate this article to their spirit of helpful advice.

The observatory is constructed of 26 separate prefabricated wooden panels of various mating shapes. Each one consists of a framework of 2 x 2 or 2 x 4 pine sheathed in plywood of the appropriate thickness. The panels bolt together at the edges, forming an amazingly rigid geodesic structure. I used only rectangles, triangles and trapezoids.

The wall-dome assembly rests on a large octagonal floor of wood-frame construction covered with plywood. The floor is supported around the periphery by eight reinforced concrete pads each extending 36 inches below ground level. One additional pad supports the center of the floor, and three separate pads are strategically located between floor joists to form the telescope pier. These extend 42 inches below the surface and contain massive steel pipe extending up to floor level. A one-inch-thick steel plate is welded to each pipe to support the telescope feet.

Two large, straight shutters protect the 5′ x 10′ opening extending from the zenith. A small "drawbridge" lets me observe the horizon when desired, but it is normally closed, providing excellent protection from wind and ground-level lights.

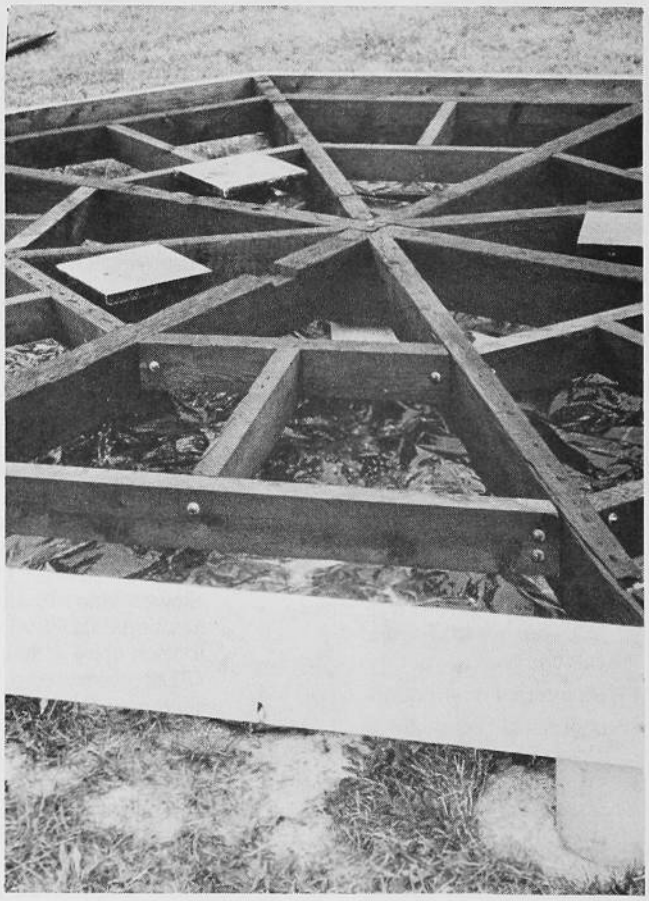
The entire structure was designed with one-person buildability in mind. No panel or section weighs over 60 pounds; each is built in the convenience of the shop and out of the weather. Panels are quickly bolted together using ¼″ lag screws and a nut-driver bit in the ⅜″ drill.

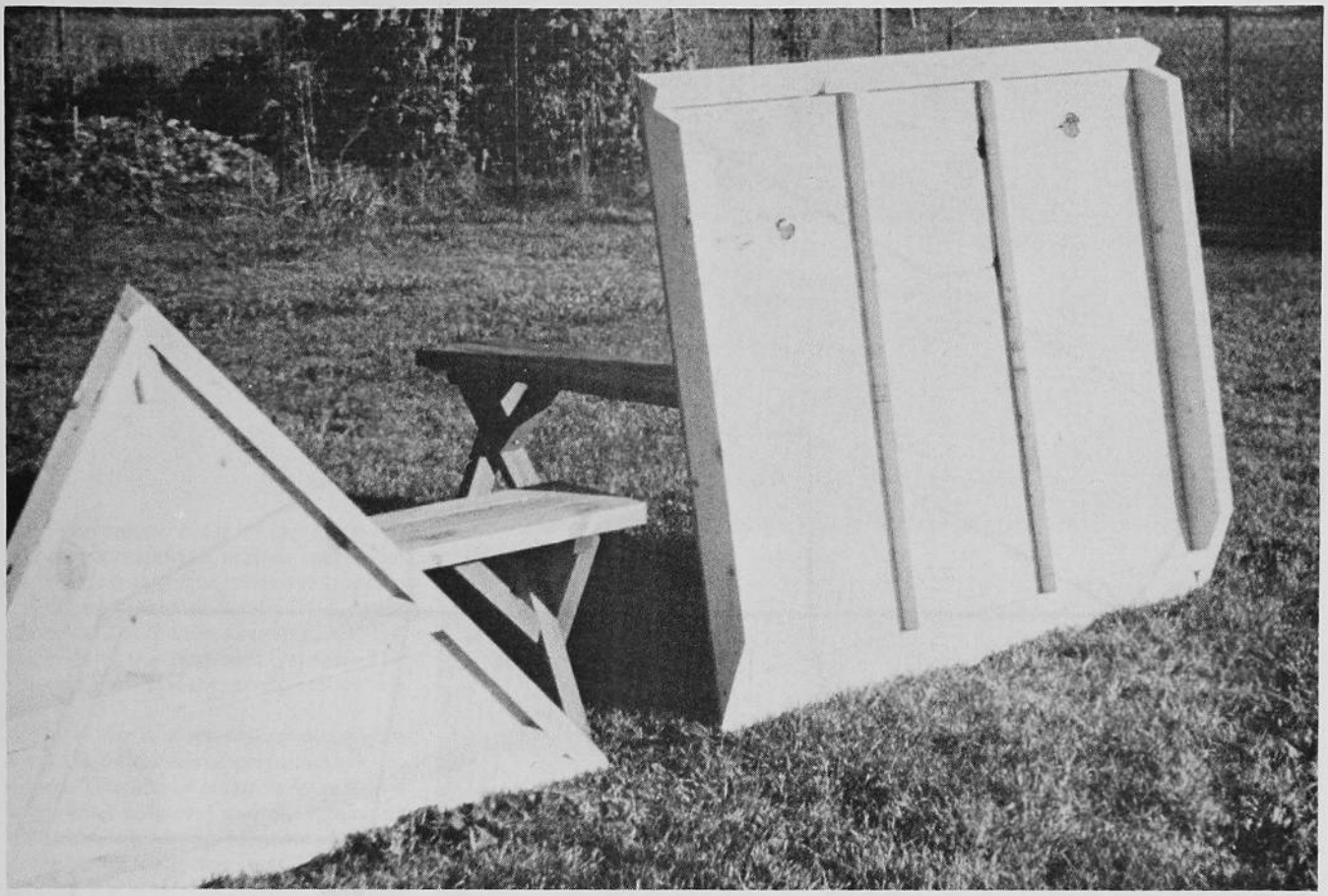
The highest panels can be positioned from an eight-foot stepladder, and the building can be disassembled with equal convenience and hauled to the new site in a small truck. I estimate that a new foundation could be completed and the observatory re-erected in two weeks spare time.

Design Details

I will describe the structure from the ground up, in the same sequence that it went together.

The foundation is concrete poured into postholes located at the corners of a regular octagon, with faces oriented north-south. The face-to-face diameter is twelve feet. One additional hole is





located at the center of the array. Each hole is 12″ in diameter at the top, and flares to 16″ at the bottom, 36″ below ground level. A steel reinforcement bar extends the full length and 6″ above ground level.

The concrete is poured to 2″ below ground level, then allowed to harden. The tops are painted with hot wax, then 12″ sections of 8″ diameter Sonotube are centered on each. (Yes — imagine using Sonotube for something other than a telescope tube!) Concrete is poured into the center cylinder to 2″ from the top and allowed to harden with a threaded concrete anchor extending 8″ above the concrete.

The center is done first. Its anchor serves as a pivot for the layout of the rest of the structure. The other eight cylinders are poured level to the center one, with anchors accurately located relative to the central pivot. The obvious tool to aid in this setup is a long, radial arm with a carpenter's level attached.

The reason for the two-stage concrete construction with wax between is to allow the ground to be easily returned to its original appearance when the building is removed. The top cylinders can be broken away with a sledge; they will separate at the wax interface. The re-bars are cut off with a torch, and topsoil and sod used to cover the holes.

The telescope piers are three sections of steel pipe potted into post holes with concrete. These holes are strategically located between radial lines connecting the building foundation pads, where the floor joists will run. They may be positioned one north and two south, or vice versa, as your instrument requires. I placed them two feet from the center with the single pad to the south. These holes are extra deep, extending 42″ below ground level. The pipe is 4″ in diameter, ¼″-wall steel. Inch-thick steel plates, 10″ on a side, are welded to the tops. The plate surfaces should be just at floor level.

Floor structure is symmetrically laid out like a huge spider web: 2 x 8 lumber with 2 x 4 crossbraces. I bought old lumber from a refurbished house. Waterproof it: lay black plastic vapor barrier on the ground before constructing the floor structure; coat the joists with Creosote.

Bolt it together with ¼-20 x 3½″ lag screws, in case you wish to disassemble it some day. A nut-driver attachment for your ⅜″ drill is a must, since the finished structure will contain several hundred of these bolts!

The concrete anchors run up through the radial joists and are bolted down. Run wiring to the center of the floor, if you wish. Cut and screw down ¾″ plywood flooring; include holes to allow clearance for the nuts on the concrete anchors. This also permits the entire structure to be bodily removed in the future, if desired.

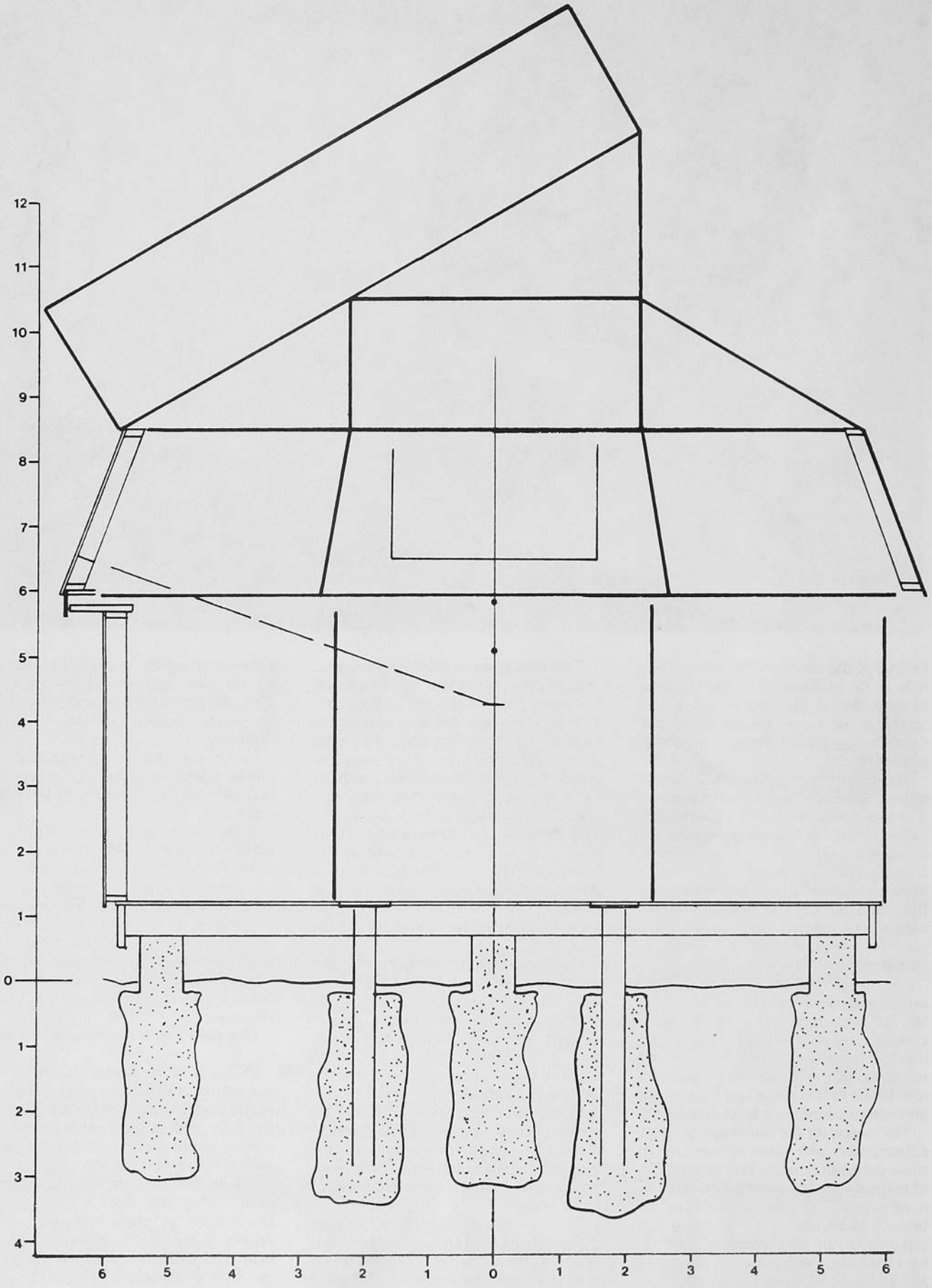
Leave the center bolt exposed for pivotal reference. If you wish, cover the floor with linoleum before starting on the walls.

The walls are eight identical rectangular panels, 48″ high and 60½″ wide. They are 2 x 4 frames covered with ½″ plywood. Cut the angles so the sections mate perfectly. The toughest part of making all of your panels will be to lay out and cut all of the compound angles involved. I did mine with an adjustable 7½″ hand-held circular saw, but a radial-arm saw would have made life easier.

One panel has a sturdy door built into it.

Prefab all of the panels beforehand — in a matter of two hours you can bolt all of the prefab panels into place. Bolt to the floor and to each other, using lag screws of the appropriate length. Extra braces strengthen the top corners.

The wall ring is a track for the wheels attached to the dome. This ring is constructed in place, consisting of a double layer of ¾″ plywood. Screw oversized sections to the wall top, then cut them to size with a heavy-duty saber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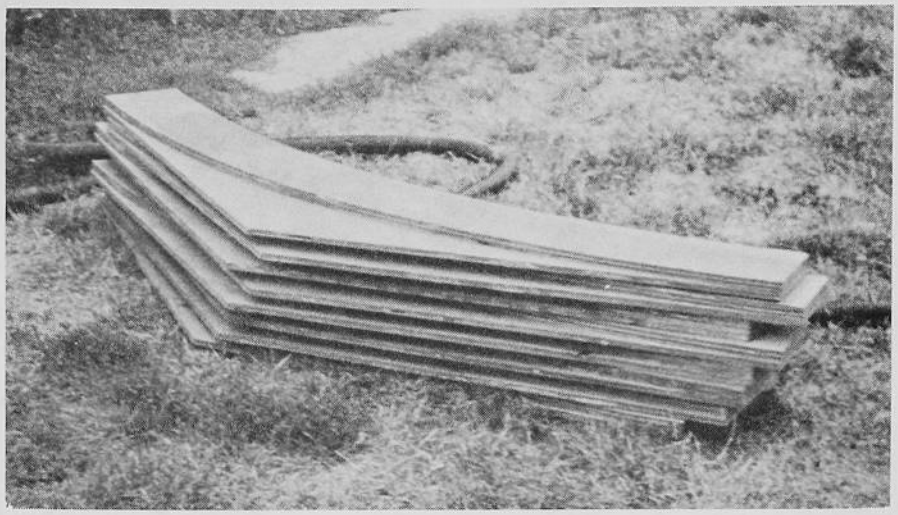


saw. You can lay out the exact circles by pivoting a crayon or marker pen about the building's central reference point.

The completed wall ring is 159.5″ outer diameter, 134.5″ inner diameter, and 1½″ thick. Seal the ring with varnish. The rotation track will eventually rest on this ring.

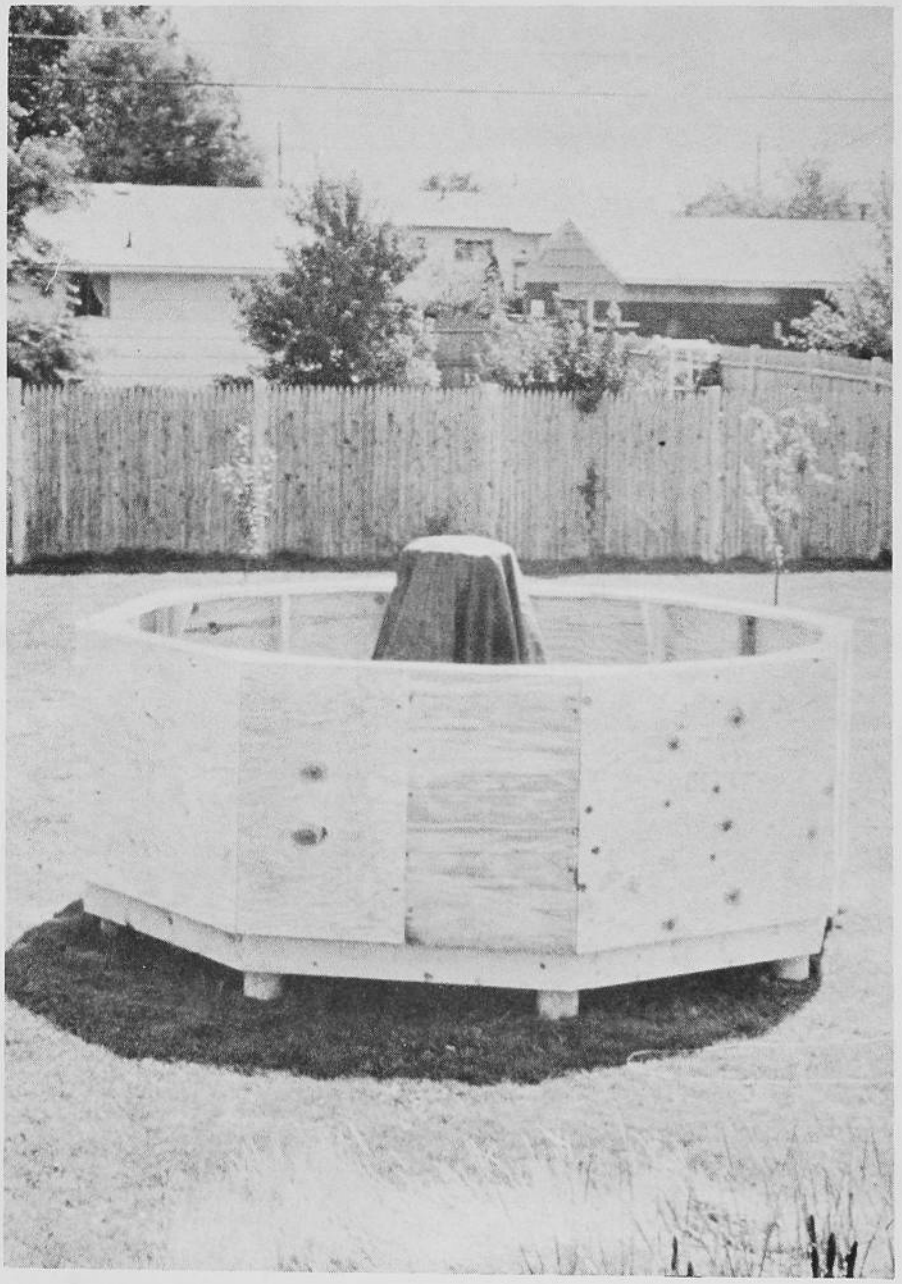
The dome is assembled in place atop the walls, before the wheels and track are added. This allows accurate layout on a solid, level base and entirely eliminates the problem of lifting a finished, half-ton dome onto walls five feet above the ground. It is assembled in three tiers: the dome ring, the lower roof, and the upper roof.

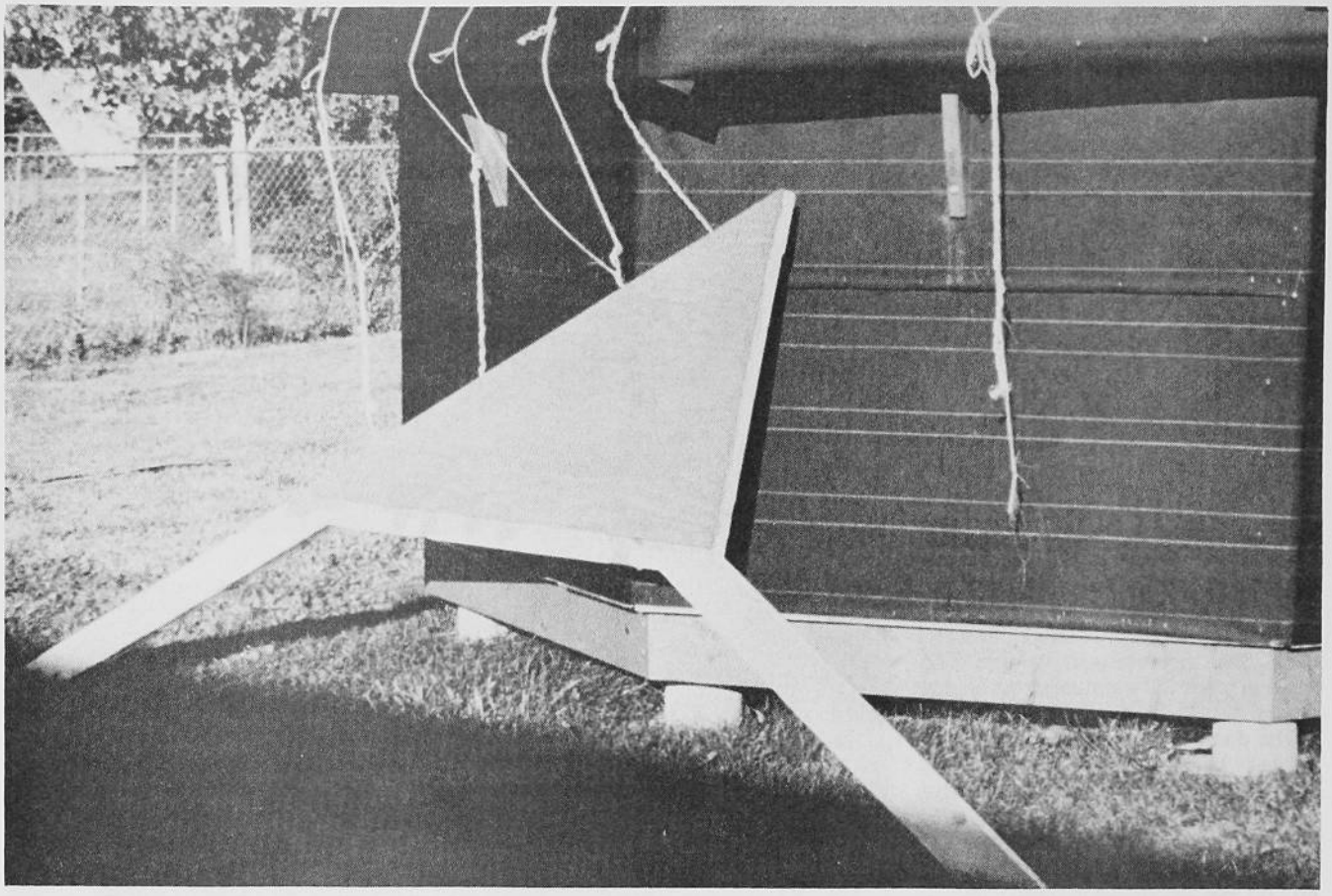
The dome ring is fabricated in eight identical sections. Each consists of two layers of plywood glued and nailed together. The lower layer is ½″ plywood in the form of a 22½° annular arc with inner and outer radii of 74.75″ and 80.5″. The upper layer is ¾″ plywood. It matches the inner arc and ends of the lower layer and overlaps the outer arc as a slightly oversized circumscribing octagon, point centered, with face to face diameter of 161″. The eight ring sections are carefully arranged on top of the wall ring and temporarily tacked in place with #6 common nails.

The lower roof consists of eight identical prefabricated trapezoidal panels made from 2 x 2 pine and ¼″ plywood. The framework is produced by ripping 2 x 4s at such an angle to cause the panels to mate perfectly upon assembly. The outer skin of each trapezoid measures 67.2″ and 55.4″ at base and top, respectively, with a height of 33.5″.

One section is built in the form of a U with an opening 38″ wide and 25.25″ high. The drawbridge will attach here for telescope access to the horizon. Be sure this panel is extra sturdy.

The plywood sheathing should overlap the lower edge by ½″ to allow water to run off. Screw the first two panels together, then lift them onto the dome





ring. Add additional panels one at a time until the lower roof section is completed. Carefully center it and bolt to the roof ring with ¼″ carriage bolts from below. Add extra bracing as you feel necessary to the upper corners for strength.

The upper roof's design is the key to the entire structure. Opening the roof from the horizon to beyond the zenith severely weakens the natural strength of the dome geometry. My solution is to span the slot with two A-frames defining the sides of the opening. These are constructed of 2 x 6 lumber and span the upper corners of two opposing lower roof panels. One side of each frame extends beyond the zenith to allow full access through the huge 5′ x 10′ opening. The frames are notched at the bottom to aid in positioning them, and are temporarily propped in place using opposing ropes nailed from the tops to the lower roof section.

The keystone panel connects the vertical sections of the A-frames, locking them together and fully defining the observing slot. This panel is 55.9″ wide by 31.9″ high. Installing it is the most precarious part of the construction — I used temporary attachments, allowing me to hang the panel on the frames and lock them together. After I drove the lag screws home, I removed the temporary fixtures.

Three upper roof panels, rectangles 55.9″ wide by 46.5″ high, and four isosceles triangles, 55.9″ at the base by 35.9″ tall, are popped in place and screwed to their mates. These panels use ⅜″ sheathing, which is stronger than the lower roof panels since they may accumulate snow.

Shutters are constructed of 2 x 2s sheathed in heavy-gauge corrugated fiberglass roofing panels. They are 29.5″ wide by 116″ long. They are prefabricated in the garage, then lifted into place. I used five hinges along the side of each shutter to attach it to a ten-foot 2 x 4, which is in turn attached to the A-frame with lag screws.

The fiberglass is positioned so that one shutter's skin overlaps the other by two flutes, or about 4 inches. This provides a good seal against rain and allows the shutters to be opened even when there is some snow on them — and none will fall in. Chains at the tops of the shutters allow them to be pushed open from the bottom end to about 30 degrees beyond the vertical, thus permitting a totally unobstructed view of the heavens.

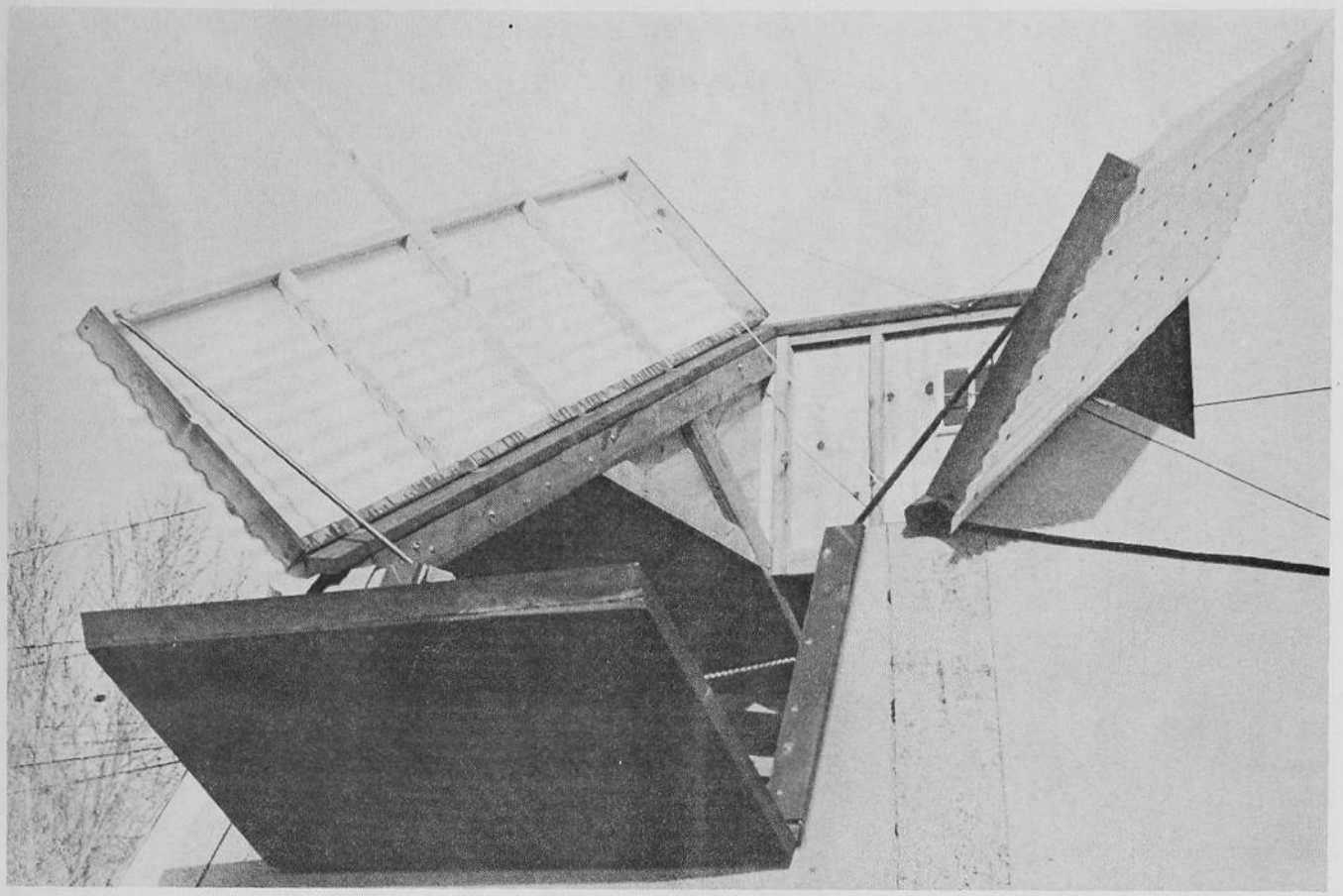
Half-inch tempered copper pipe struts connect the bottom corners of the open shutters to the lower roof section to keep them from blowing closed in a stiff wind. When they're closed, spring-loaded nylon ropes automatically drop from the upper corners, and are hooked to the lower roof section, battening down the upper edge. I used eye bolts and hooks to batten down the lower ends.

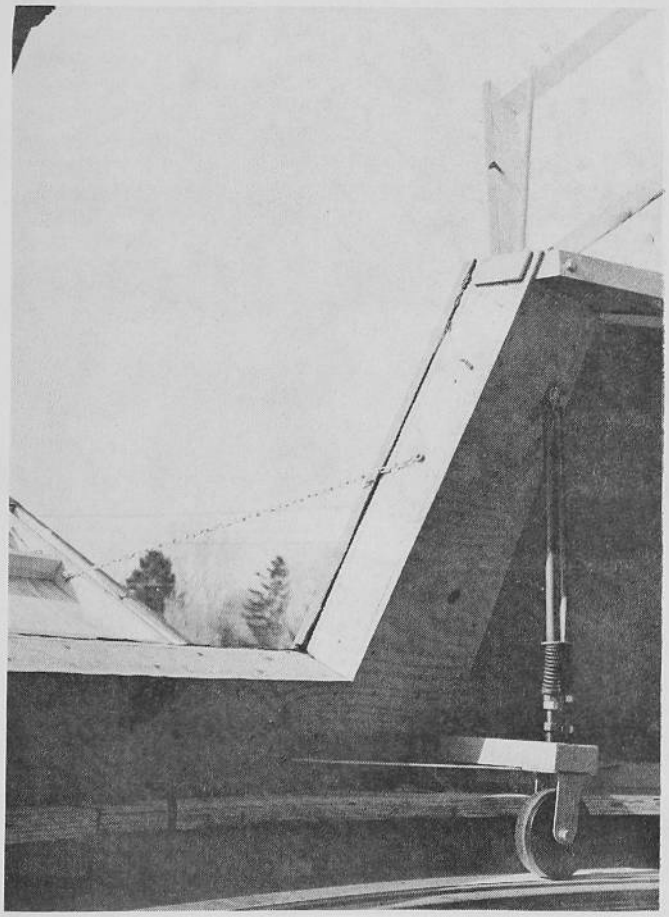
After the roof is built, the rotation track is installed. This consists of a 4″ wide ring of ¼″ thick tempered Masonite, centered on a radius of 71″ from the building reference. It is constructed in sections about 4′ long, with the ends butted at an angle to prevent the wheels from clunking as they pass over the cracks. Nail them in place with small brads along the outer edges, then glue Formica to the Masonite with contact cement. Allow ½″ clearance on the inner and outer edges, so that the track can be removed at a later date without damaging it.

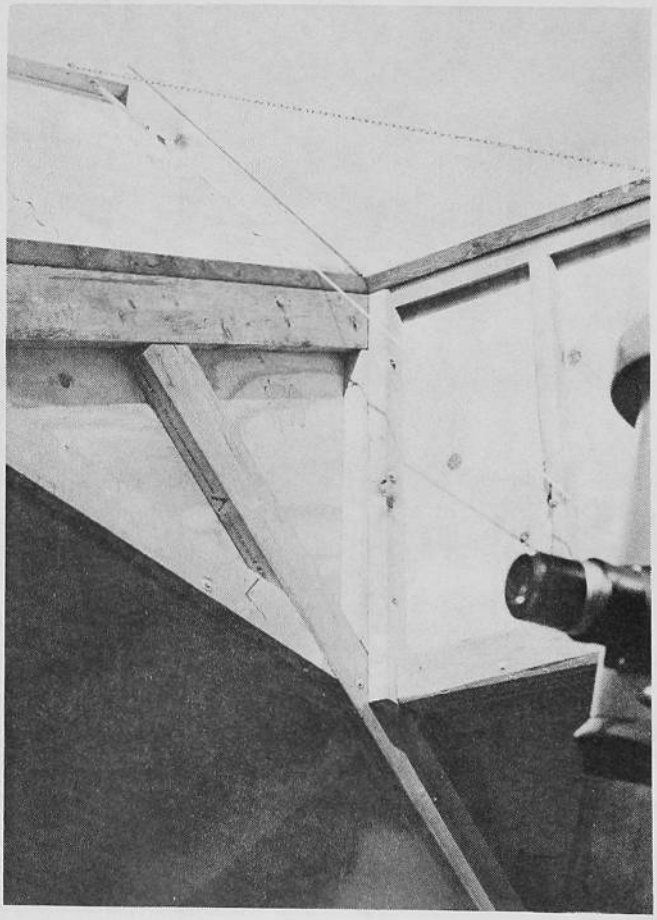
The eight rotation wheels are 6″ diameter industrial hand-truck wheels. Use "rigid" wheels — those which do not pivot — and avoid casters. I found hard rubber or plastic tires are best, and ball bearings are desirable.

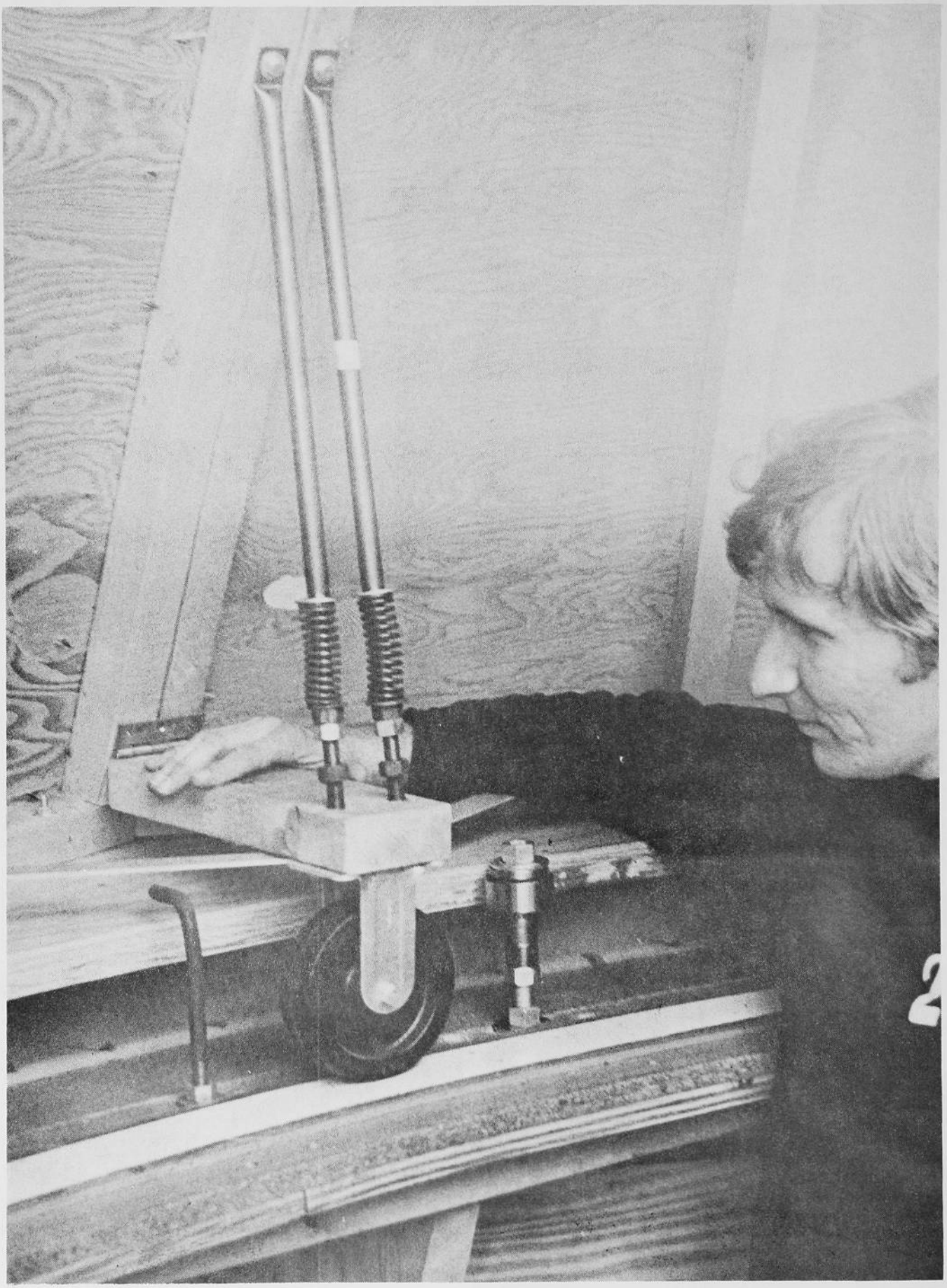
I designed the wheel mounts after hearing the problems friends have had with their domes. The dome track will not be perfectly flat, no matter how hard you try. Therefore, as you rotate the dome, some wheels will bear the load, while others hang with no load. This introduces severe forces that distort the dome, causing it to moan and groan as it is rotated.

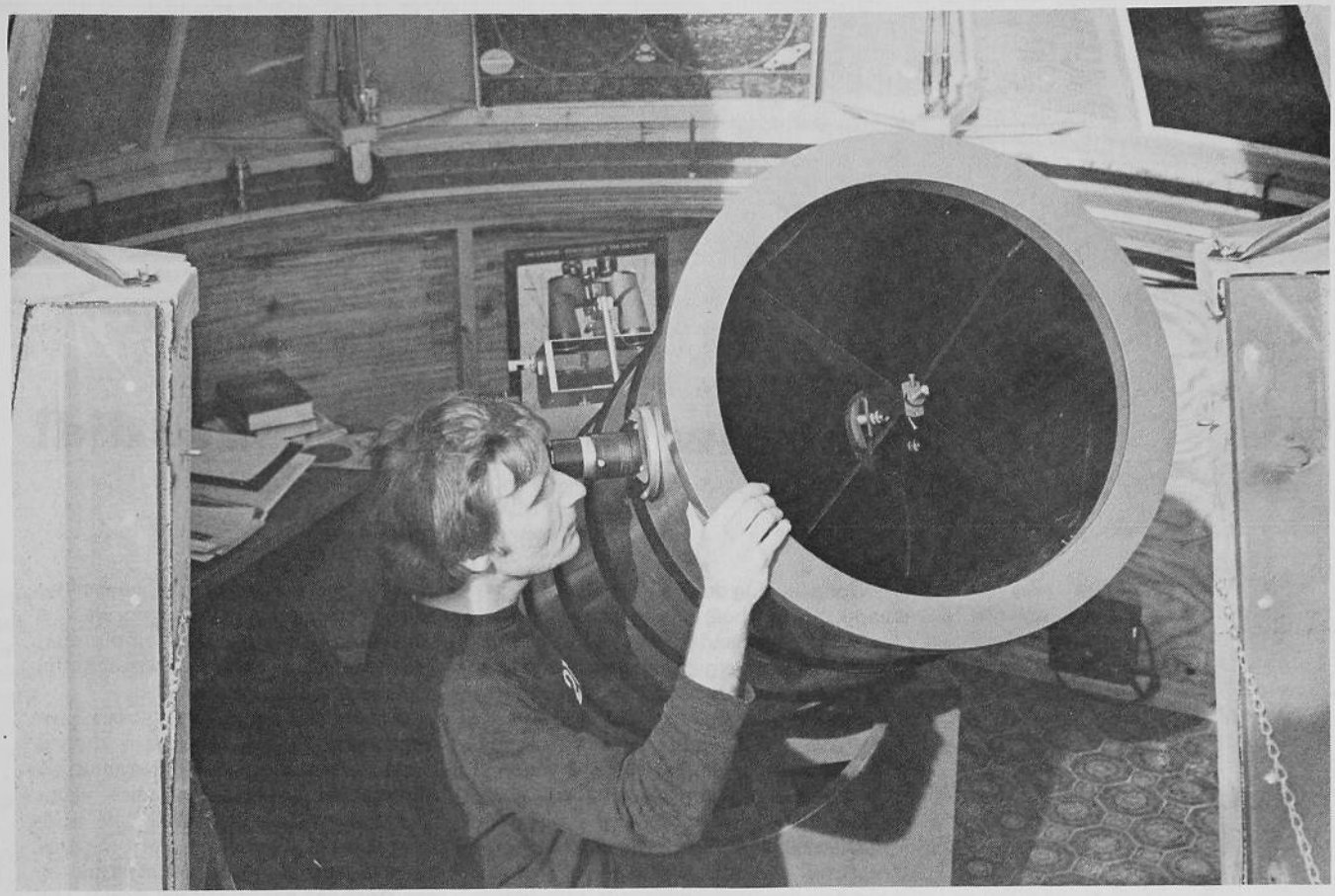
I overcame this problem by spring-loading each wheel with a unit made of ½″











hardened copper water pipe, steel rods, and springs from the hardware store. These act as compression bars, analogous to shock absorbers. Select springs rated at 100 to 200 pounds per inch, and a few inches long. Buy a total of 16 — two for each of the eight wheels.

I installed the wheels by first raising the dome to the required height with a bumper jack between dome and wall ring, gradually working my way around and raising it about ¼" per circuit.

But wait — before you raise the dome, install guide rollers! These keep the dome rotating about the true center. I used four ball bearing heavy metal wheels, 3" in diameter by 1" wide, held on a length of ⅝" threaded rod and securely bolted through the wall ring and wall frame. Locate alternate holes ¼" outside and ¼" inside the "correct" radius to allow easy adjusting and centering of the dome. The height of each guide roller is adjusted with nuts on the ⅝" rod. The guide rollers bear against the inner surface of the roof ring.

You'll also need safety braces around the periphery of the wall ring. I installed eight. These are ½" diameter steel anchors normally used in concrete, turned upside down and hooked over the wall ring but not touching it. They will keep the roof from coming off in the event a guide roller breaks or a hurricane decides to test your handiwork.

On the outside, a skirt ring protects the lower edge of the dome. I used 6" wide strips of plastic-coated masonite paneling screwed to the outer circular edge of the roof ring which allows ¾" clearance all around. I added a flapper seal as well — it's a long strip of foam rubber ⅜" thick and 3½" wide nailed to the wall ring and bent up against the skirt ring. Its natural springiness keeps it tightly yet gently sealed against the wind and weather.

The dome is covered with standard roll roofing; the walls are covered with paneling which simulates delicate but rustic clapboard. Exposed lumber is sealed with Cuprinol brand stain and wood preservative.

The Observatory in Use

Upon completion of my observatory, I found that I was doing far more observing than I had in the past. There are two explanations. First, the mere fact that one puts hundreds of hours and dollars into its construction assures a certain commitment to justify the effort. But even after that initial thrill wears off, you will continue that heightened level of observing, both more frequently and for longer sessions. Why? It seems to be a matter of convenience. If I wake up at 3 a.m. and notice that the skies are clear — not that common here in Rochester — I can be observing a few minutes later with a large telescope.

And an hour after that, I'm back in bed, having enjoyed a comfortable observing session with virtually no set-up or tear-down. I never would have hauled out my 6" telescope under the same conditions. As a consequence, I have seen and enjoyed more celestial splendors in the past year than I did in the last twenty. From my experience, I can predict that an observatory will insulate you from the daily world and open you to the universe.

Epilogue

In a few months, a $60 million shopping mall will have its grand opening. It is located a half-mile from my suburban home. Just last week, the original forest of stately trees was finally replaced by a forest of parking lot lights.

Soon they will throw the switch. So next week my house goes on the market, and I'll be looking for a new home on the crest of a remote rural hill. My observatory is in the back yard waiting — and I'm glad I'll be taking it with me!

Tom Dey
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■

Got a leaking dome? I sure did!

Got a leaking dome? I sure did! In the early sixties I built my first observatory — and it leaked and got wet inside. Well, I finally solved the problems, and I think I can offer some hard-won advice to anyone in the same fix I was in.

I have always felt the literature was in need of a single, comprehensive source on observatory construction and site selection. To be sure, there are some basic principles involved related to tools, material options, design options, construction techniques, site selection, optical-environmental considerations, and the like. And there are some excellent articles or chapters in various books available. But they're spread too far and wide — and some of the best information is buried in professional journals and private papers.

I started my first project with a long list of "intelligent" questions and had to start actual construction short of getting these questions answered. A book would have saved me a lot of time and waste, then and over the years, and I'm definitely ahead of the game to begin with because of my rural background and familiarity with basic construction techniques. A book of this kind would be an excellent project for anyone experienced and so inclined with some kind of quasi-professional background.

Since my first project, I've seen a lot of observatories and have been consistently impressed with how most of them start in the middle. Nor does the fact that a club or group built an observatory automatically guarantee better results. Collective ignorance is sometimes worse than individual ignorance! It's always best to start at the beginning.

Far and away, the worst work I have ever seen is with spherical domed observatories. Better work turns up on the segmented conical varieties where flat sections can be joined with well-formed joints; then come the four-sided peak varieties; but the best of all are the conventional, flat-roofed roll-aways. The problems encountered seem to be proportional to the number of curved surfaces in the design.

But there are simple techniques which can produce a well-formed, structurally sound spherical dome. Somehow these techniques usually elude the average builder, whether through lack of experience or because most builders are automatically inclined to think in terms of square-cornered house construction. The builder reasons: "There must be a square way to make a round surface!"

Let's begin with cutting circles and solve this mystery. I have seen unusual methods applied to drawing and sawing long radius arcs — don't use string or flimsy wire or handkerchiefs tied together for a radius bar. Get whatever length of stout wood is required, or a piece of pipe. For the center, drill a hole near one end in the wood; in pipe, don't drill a hole through it, attach a T-fitting. Whether wood or pipe, drive a peg through the hole into the ground; and I mean "drive it" — anchor it solidly.

Now you have two options: to draw or saw. Pick a flat piece of ground and lay down a 4 x 8 sheet of plywood as your drawing platform, or some lengths of 2 x 4 if it's sawing you are going to do. The 2 x 4s raise what you are sawing off the ground. Mark off the length which corresponds to the radius you want

(remember radius is half the diameter!) and for wood, nail a couple of finish nails on either side of a pen or pencil. For pipe, simply tape two rings of masking tape either side of where the marker must be. The creative craftsman can devise a more permanent arrangement.

For sawing directly, attach your power saw centered on the radius mark. I highly advise using a sabre saw (over a circular saw) both for safety and because small arcs are difficult for circular saws. I attach my sabre saw with large hose clamps for a rigid assembly, and it works. It will give you accurate cuts — and with accurate cuts all your construction is more sound.

This said, let me touch on several other basics:

Materials: I think masonite is a difficult and marginally-sound medium to work with. Whether tempered or not, hardboard is really not weather-sound. If you use it, you must protect it, and whatever protection you use, you'll face the problem of how much protection you can give it.

Because of its makeup, hardboard has a habit of letting go, whether nailed, screwed, or glued. Where it's nailed flat over conventional support spacings, it will hold; but where it's nailed and stressed into a curve, it's subject to coming apart at the points of nailing. Used as a core between two fiberglass sides, it is fine — or as a frame or mold for forming a fiberglass shell. But as a finished wall, it simply is inferior. You lose when you think you are winning.

Most amateur observatories I have seen suffer from the materials used in them. It's not because it is cheaper to use the wrong materials — it is in reality more expensive — but because of the wishful mentality that says "we think such-and-such will work" — the wish being father to the thought.

The key is using the right materials in the first place. And in using the materials in the right way.

It is well worth noting that domes vibrate. Imagine a large shell out in the wind. If the internal supports are not well thought out, regardless of how thick the shell is, trouble looms. Professional observatory domes are engineered to provide shell support and to absorb and "negotiate" vibrations and shocks which move through their structure. They have a wind-rating, an estimate of how well they will withstand external forces.

Most amateur observatories seek to establish a well-formed, strong, rib structure on which the shell virtually hangs. Masonite domes fall into this class — the masonite does virtually nothing to hold the dome together, and it may very well be acting to break it apart.

You must provide some relationship between the shell and the internal support. Either one holds the other up, or they complement each other into a whole. If they are virtually independent of each other, then the Fates are holding the whole thing up!

Given vibrations, stresses, and shocks resulting from cross vibrations, if the materials and the structure are not intrinsically sound, then the nails will loosen, the seams will crack, micro-cracks will appear on joints, externally applied beads of caulk will lift, and the next thing you know your observatory is wet and leaking when it rains. If your primary material is masonite, the next stage is literal deteroration; and your observatory falls apart.

"Beefing up" a badly designed dome doesn't help. It may speed deterioration. What is required is a sound, integrated structure to begin with.

Glues: No. Elmer's type glues, none of them, are waterproof. When dry, they will melt with water. My experience is this is the case with all the "alphatic resins" which are water-based.

But lumber yards are full of experts. Likewise paint stores. It does not surprise me that they'll tell you Elmer's Carpenter's glue is waterproof. After all, it says right on the bottle "Professional." And anything that says it is "Professional" has *got* to be waterproof, doesn't it?

In the right context, water-based wood glues are wonderful. One of the things that makes them wonderful — along with holding well while dry and offering a flexible, strong joint — is that if and when they ever do let loose, they can be soaked, the old glue wiped off, the joint cleaned and dried, and a fresh new joint made with a new application of glue. They are *meant* to be water soluble! They are conducive to the inevitable repairs of the real world!

This leads to an axiom: You can ask a salesman for advice, but if you want good advice, try people who actually do what you want to do, who use the products you are considering using.

I know — we are all victims in the present social uncertainty. It used to be people in lumber yards and paint stores had hands-on experience, and in the midwest that usually meant retired professionals. That is no longer the case. Your expert at Little Bandit Lumber Co. may have been selling "a piece of the rock" the day before.

The same general principle applies to machinists and other trades that were once pure professions. If you are looking for a fine instrument machinist, do not engage a welder who has never worked with a piece of steel less than four feet long and two inches thick. They will try to do what you want them to do, but there is every chance that five tries and six weeks later, you will still be waiting; and you will NOT get your money back. I know from

personal experience, sad to say!

I cannot recommend any "glue" as such for holding an observatory together. It is not 2001 yet! The "casenite" glues fracture and crack, and just as the ads say, they are stronger than steel. Yes, you have an open joint and to one side or the other a nice "blot" of "stronger than steel." Get out the file — or try a hammer first and knock it loose "carefully." Try crushing it — or try not using it in the first place.

Hot glues. They are hot, but whether animal or plastic they are all inappropriate if not useless to the purpose at hand. Have you ever seen what hot glue does on a hot summer day? Likewise hot melt plastic glue at -10°? The point should be obvious — whatever glue is used must withstand the thermal extremes present in the out-of-doors.

There are glues which would work. Science has created them, yes. Some hold jet aircraft together, along with a few well-placed rivets, but they are not appropriate. The only gluing medium I have ever found which works in the context of an average amateur observatory is the polyester resin used in fiberglassing, applied between joints which are otherwise fastened together adequately by screws, the proper nails or rivets. The longer the drying time of the resin used generally, the greater the holding strength. For metal glues, write me. They are not appropriate to ordinary usage.

Caulks: Caulks are not glue. Caulks have a specific use intended. Caulks are not a panacea. Caulks cannot undo poor construction. They can be used as band-aids until the underlying wood is cured, but generally they should function as a "seat," a "cushion," as an "in-between seal," or as an "underneath seal." They should remain intact and flexible at all temperatures common to Earth! Caulks should be part of an otherwise sound and well-formed joint or assembly.

I have seen countless examples of caulks applied externally to a surface, as on a roof, over a joint, in a large run of beaded rope, where in fact micro-seams had developed under each edge of this rope and the caulk had for all practical purposes lost contact with the surface it was supposed to be sealing. In each case, the builder would look at this caulk job and protest he could not imagine where the water was coming in!

I would apply a trim piece over a joint with caulk sandwiched in between the trim strip and the roofing surface before I would "run a bead of caulk" to try and seal a joint. I have heard it ten thousand times: "Oh, just run a bead of caulk."

There are of course many kinds of caulks, again each with a specific purpose; and caulks good for one year, two years, and twenty years. But consider this: cut-up strips of old innertube are also excellent "gaskets." In many cases, a gasket is what you really need and what you are trying to form with the caulk you're applying. Caulk does seal better around nails and screws, if you are using the right caulk. Otherwise, consider a rubber (innertube) gasket.

If you ever have to remove built-up caulk or roofing compound, pick a cool day and try pulling it off in strips. I am down on roofing compounds except in an emergency — whether cold or hot, they are a mess to work with or around. And yes, melted waterbased glues will dry and cure. They form into a scab and while they never have their original holding power, they are sometimes a problem to scrape loose. Try a putty knife.

Paints: Latex paint breathes! It is designed to. It is appropriate for house walls because it lets condensation inside house walls out and permits a slight air flow. Moisture can pass either direction through latex house paints. There are water-barrier paints for cement block but they are simply not appropriate to a wood surface or to metal.

Frankly, in lieu of some better remedy, water-based latex paints applied to masonite might be worth a try to stop general leakage. I think the paint would crack at the joints, however. Again, I recommend a real cure over a stop-gap measure. Paints are expensive.

Latex paints on untempered masonite are a disaster! It is like trying to paint old bark. Even on tempered masonite, some sealing is required before the surface will take paint. In any event, painted masonite does not look good and it is not durable. I do not advise latex over metal, plastic, fiberglass, or foam.

The paint you choose for an observatory must serve a very practical purpose and serve it well, and also present an aesthetically pleasing appearance. My personal opinion is an observatory should look good — but also look like you mean business. Ordinary latex house paint is appropriate to your supporting walls if they are a conventional house-wall construction. But for the dome and inside the observatory, I advise an enamel. It looks good. It looks "professional." And it is durably utilitarian.

A clean observatory is an absolute must! I am a bear on this topic! There is no excuse for anything other than a clean observatory outside of incapacitating illness, urban pollution, volcanism, or mud rains! Everybody is happier with a clean observatory. You work better. You can take pride in your clean observatory. Anything short of this mounts to sloth! I know college observatories that are just plain filthy. It throws into question the whole program itself. You should, in fact, have an observatory from which you can remove the telescope and other vitals, go out with hose, a bucket, a scrub brush and a scrub broom, a dozen rags, a can of Pledge, and plenty of soap and play dutch maid 'till the cows come home!

Short of this, you should have a paint on both the interior and exterior of your observatory which will take consistent upkeep and cleaning. The necessity for cleaning should need no explanation!

I prefer enamels — and providing the proper precautions are taken, I prefer them spray-painted. You can spray-paint the interior of a sixteen footer in an hour if you start from an organized state.

There are enamels appropriate to every material — metals like tin and aluminum require special primers prior to the finished coat, and there are enamels for fiberglass.

Ventilation within an obervatory is a sheer necessity to control moisture. It goes without saying that ventilation alone cannot cure leaks, but it can dry them out and it can prevent equally serious moisture problems. Again, I think the amount of humidity vs. dryness is a matter of balance — too much of either causes problems.

You cannot tolerate air currents inside the observatory. You cannot tolerate high velocity air currents through the observing slot or passing in front of it. I am no expert on this, but I will tell what I do know and what I have done myself.

I took coffee cans and cut the ends out, installed a "quiet" slow moving Rotron fan that had plastic blades, one per can. I made stops out of plastic and made filters out of fine weave cloth and cotton and placed a filter in each can so any air incoming would be filtered. I wired these into one central switch, and I placed them around the walls of the observatory: two blowing in and two blowing out.

Two of these I mounted near the dividing line between the side walls and dome, one each about two feet either side of the slit. Since the slit was fairly wide to begin with, I am sure this fact alone tended to eliminate high velocity corner currents, but the combination of vents and slit made for what I felt was a very balanced situation.

On cold nights it helped to prevent condensation — the same for warm humid nights. And many days when I felt there was some cause to worry about moisture levels in the air, I left the fans on. Air flow is vital for suppressing condensation.

Now I did not come to this arrangement without some precedent!

My first observatory lacked these features. Because of a poor choice of materials, it absorbed moisture like a sponge. It began to fall apart and the ultimate horror was that fungus grew on my mirror! With that, Dudley Clausing of Skokie, Illinois gave me a quick, sympathetic education.

It turns out that there are fungi which will attack and "eat" mirror coatings, and unless my memory is faulty, there are other fungi and bacteria which will literally "eat glass" under the right conditions. A very humid environment is where these fungi start. So I had to have my first 12" mirror recoated!

With my second observatory and the vents installed, I had no further problems. My second observatory was a quantum leap over my first, in every respect. As a further precaution, I installed a dehumidifier which more than cured the problem. I piped the outflow from the dehumidifier through the wall to the downhill side of the area where my observatory stood.

As an added bonus, the dust level inside my observatory went down, so I made two more vent fans and installed them in my darkroom. It was a different world. Dust control is also something to consider inside an observatory.

But NOTHING is going to replace a well-structured building in the first place. For a leaking masonite dome, I recommend two options, either of which will solve your problem. The first is to tear off the masonite dome siding and lay on a new skin; the second is to leave the masonite you now have in place and use it for laying up a fiberglass shell. The result will be a fiberglass dome with a masonite core — something you could have started out to build in the first place.

Of the options, each has its pluses and minuses. If the ribs have started to come apart from water damage, or if the masonite has seriously let go of the supporting ribs, you may have to replace the whole skin. Let me cover that first. At this point, start thinking of your dome as something akin to a boat. Get what is sometimes referred to as "utility cloth" or "wire lath," cut it into sections and form the sections of your dome out of this. Believe it or not, there are quality sailboats made with just such a technique — the utility cloth is covered with a special cement to form the hull, it cures, and in water it is flexibly rigid and performs magnificently. You can skip the cement — use fiberglass instead.

You can place your sheets of utility cloth directly on the ribs and trim them after stapling the cloth in position. The cloth will not only assume the latitudinal shape of your spherical dome, it will curve longitudinally, conforming to the compound curve of a sphere infinitely better than masonite or any thin-wood type material can. Overlap all the joints on their rib supports.

Wire lath goes up quickly with a staple gun, there are no stresses involved in bending it, and it will assemble to make up a very well-formed dome, unless you fall off your ladder and land on it! In that case, go inside and pop it out and what does not pop out, bend out smoothly with a block of wood.

I am assuming, of course, your whole rib pattern, bottom frame, viewing hole frame, etc., remain in place and "healthy." If you were starting this dome from scratch, I would advise that you not make "beefy" supports. Typical 4"-deep supports for masonite can be cut to 2½" for a fiberglass dome. You could work with ½" plywood, but ¾" plywood is preferable because it allows a wider tacking base.

Now you can cover the metal frame with certain foams, fiberglass, canvas and fiberglass, or you can go ahead with concrete and make a boat. I recommend fiberglassing. On the side of the dome where the ribs join the skin, run a 4" strip of fiberglass cloth along the full length of both sides of each rib to "join" each rib to the shell.

You could simply apply resin to the utility cloth. I have seen it done and it works, but if you can afford it, use cloth over the wire cloth. It eliminates bumps and tends to prevent running of the resin. Two coats to the exterior creates a very smooth finish which can be sanded and painted with the appropriate paint. After joining each rib to the shell inside the dome, coat the whole inside if you can. Incidentally, you can fiberglass in any "fixtures" of wood or metal you need for lights or whatever directly to the shell if you wish.

If you were working from scratch, you could have made your supports out of steel wire (like 3/16" reinforcing rod) rather than wood to start with. It is a simple matter to make a form and bend the rods to the appropriate radius, wire them together, anchor them in a base plate, and wire sections of utility cloth to the final frame. You can attach wooden frames as needed, or metal frames — whatever. It makes for a very durable and dependable home structure.

If, however, you choose to repair a masonite structure, be sure your ribs are well tacked to the masonite before making the fiberglass shell. Remove as much of the old Elmer's as you can and "glop" in some polyester resin to try and fill the joint between the masonite shell and each rib, then go outside and really "tack" the masonite down. You do not want gaps or spaces since the nails will work loose and could puncture any new shell.

Rough up the masonite before applying cloth and fiberglass. I'd advise you secure the ribs to each sheet with 4" strips as previously mentioned before working on the outside. Just make sure those ribs are as firmly attached to the masonite as possible through the combination of nails and fiberglassing. You could even fiberglass the whole interior before going to the outside if this is desirable.

On the outside, first place thin strips of cloth over each joint — I assume the whole outside is thoroughly roughed, and all former roofing compounds, paint, etc. are off. And everything dry. Lay those strips down every joint and work resin into the joint; smooth it out beyond the outer edge of each strip. Let this dry overnight. Then go back and cover the entire outside surface.

The slit cover can be refabricated out of a frame (perhaps your old one) and two layers of cloth and resin. Polyester resins may be tinted to have color — you may have done this for your surface coats. Leave the slit cover transparent — you'll be surprised how much light comes through during the daytime. It makes working inside the observatory during days a lot easier.

And don't forget to install a couple of screen door hooks on each side of the slit cover, and remember to hook them when not using it. I've seen them headed for Oregon in a strong wind!

In closing, let me comment that if repairs are needed in winter, use caulk or roofing caulk that has been warmed. I'd also recommend putting a heater in the observatory prior to applying any sealer to the dome. Heat the place up and apply warmed compound over the hole, joint, or whatever, if you want it to stick.

A related idea: I have seen domes that had heat tape embedded or attached for ice and snow control. Except for the cost of running them, they seem to work very well as a rule.

I hope there is something in what I have said that will be of value to you. If you ever need any ideas for the construction of "rails or faultless tracks," drop me a line and I'll try to get a letter off.

And finally, this remark: I have yet to meet a person who having had the opportunity to use an observatory, doesn't prefer it for general work. Even a poorly constructed observatory is a real plus for wind protection, general convenience, and it usually leads the amateur to desiring an even better observing room.

Best of luck.

Jerry R. Warner
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■

Letters

◄3

At present, a 256K bubble memory is in production for thirteen different business computers, and there are more every month.

What I'm trying to get across is that within ten years the average home computer will have at its disposal more working memory than the entire world presently has now. That is a prediction, not fact — but a reasonable one.

What this will mean to you and me as amateur astronomers is really anyone's guess. I, for one, do not intend to be left behind when all of this occurs. I am presently compiling all the hard data on stars and celestial objects that have been cataloged to date. It is not an easy task, but one which I will enjoy immensely.

I hope that your company sees this and is planning to take advantage of this explosion in the computer industry. Well, I hope I haven't bored you with this long letter.

Clear Skies and Good Observing!

William H. Rowland, Jr.
AIMD/GSE
N.A.S. Norfolk, VA 23511

Thicker Tube

Dear Sirs / I have been trying to locate a source for "sonotube" suitable for a 16-inch f/6 thin mirror telescope. I am looking for a tube with an 18" I.D, but can only find it with ¼" wall. I think I would need a thicker wall!

I have tried companies in Connecticut, New Jersey and Massachusetts with no luck! Help!

Any resources you can give me?

Nicholas Osborn
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Bristol, CT 06010

— I saw some ideal stuff at Stellafane this year, but the guy who had it wouldn't tell me where he'd gotten it because he'd gotten it through a friend. This tube is used for making felt, and Albany International uses lots of it. You might try the big city business Yellow Pages under "Paper Products, Tubes." Retail firms also seem to get the stuff for storefront displays, but I've never asked where they get it. Coulter Optical now sells the tube they use, but it's not the size you want and it's expensive. Have any readers had luck finding ½" wall spiral-wound paper tube?

Apodizing Away!

Richard Berry / Thank you for the report on the Riverside Telescope Maker's Conference in TM#16. Though I was at Riverside (my first), your article told me things I hadn't learned on my own. Keep up the good work!

I was struck by your comment that Art Leonard's Yolo TCT gave the best images of the night, but that you'd like to see it in action without the apodizing screen. Well, the irony of that statement is this: the very reason for the telescope's performance (in poor seeing) is that screen!

You were within a few yards of my 8" f/6 Newtonian when photographing Walt Schoendorf's Dobson (p.24), and I was touting the screen to all who would listen as a seeing filter. My vehicle was the blue and white VW bus sporting the 9-foot CB antenna, parked just south of Pete Manly.

The apodizing screen is promoted as a device to improve resolution of a telescope. But I discovered that it also functions as a "seeing" filter. This is because the action of the filter is to remove the diffraction rings, substituting the spectra. Seeing affects the rings much more than it affects the central peak, so the unstable component of the image is much attenuated.

On a scale of 1 to 5, an apodizing screen improves seeing by about 2 points. Due to the spectra, it is useful only on a planet or double star; but when seeing is really poor, it gives a very useful improvement on the Moon. On the Pleiades the result is utterly incredible!

One of those to whom I spoke at Riverside was Dennis Di Cicco, who was kind enough to mention it on page 184 of the August *S&T*, and even ran a picture at the bottom of that page. However, the specifications given there have been improved upon.

At the AANC/WAA Conference at NASA/Ames in September, I was shown an apodizing screen that, according to its builder, is as much better than my own as mine is over an unaided telescope. I did not catch his name, though he had observed with me at Riverside. He uses his screen along with a 6" off-axis stop on his 13.1" Odyssey. He made a copy of my screen, then made several more, trying different parameters. He recommends: 1) Cautiously spray-painting each layer of screen; 2) Using ⅛" mesh screen with fine wires, sold here as "fruit-drying cloth"; 3) Using five layers, with openings ranging upward from 65% of full aperture.

I don't know the specific sizes he used, but I intend to try 64, 72, 80, 88, and 96% of full aperture, and to turn each layer 18° from the previous layer.

Perhaps someone in Milwaukee (where I attended Marquette University, BSEE '63) will experiment with the apodizing screen. We all complain about the seeing — now here is a chance to do something about it!

James H. Van Nuland
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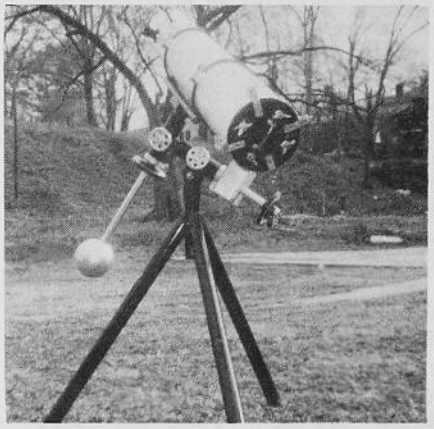
San Jose, CA 95124

— Thanks for providing some useful background. The purpose of an apodizing screen, as I understand it, is to create a Gaussian distribution of light across the mirror which results in a Gaussian distribution of light in stellar image (the disk and rings being a Fourier transform of the entrance pupil). So far so good. What I don't understand is why removing information, i.e., blocking photons and reducing the high frequency Fourier components, should add information to the image. Clearly it cannot; therefore I wanted to see Leonard's telescope without the apodizing mask.

On the other hand, your subjective opinion is that the image is better, that the apodizing mask acts as a seeing filter. Fine, but can anyone explain why? It would it seem that you're enjoying the "Questar Effect," which often gives a small, high quality telescope an advantage in poor seeing. Perhaps an acute and mathematically inclined physical optician will explain for us. . . .



Golden Hammer

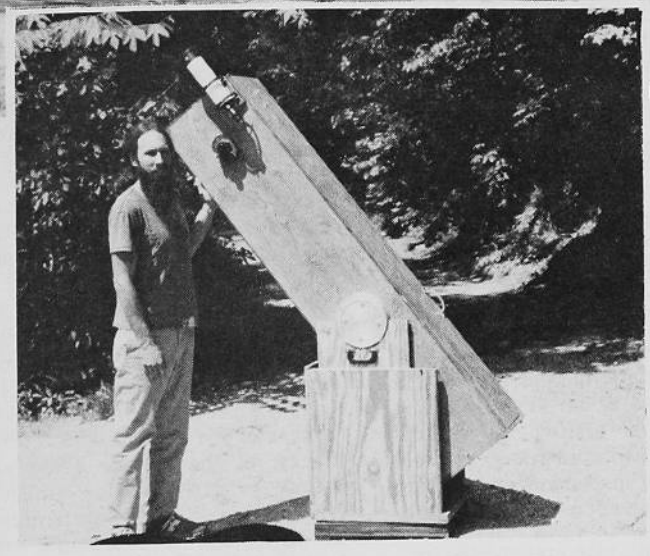
Sir / Enclosed find photo of my homebuilt 8" reflector telescope. My first homebuilt was a 5" refractor, which won *Mechanics Illustrated*'s Golden Hammer award. This one was never entered in that magazine, or featured in any magazine. Now you can see why I wanted to change from ODYSSEY to TELESCOPE MAKING!

R.M.Garrett
Rt. 2 Lot 28 Creek Dr.
Cartersville, GA 30120

Fine Finish

Dear Richard / Here is a picture of my 12.5" f/6 Newtonian. The tube and Dobsonian mount are finished with poly tung oil; the trim and focuser are made from red cedar, as is the board the finder is bolted to. There is also a reinforcing ring of red cedar which trims out the front, and protects the end grain of the plywood. The mount and the optics work great.

David Blumberg
Rt. 1 Box 300
Olivehill, TN 38475



Scope Plus Shelter

Dear Richard / I am sending you a photo of myself and my 12.5″ f/6 Newtonian Dobsonian telescope which I finished recently. It has a 4″ f/4 reflector for a finder slung bomb-style under the main tube. The roll-off shelter provides protection. Dobsonians fold down low, so the shelter is conveniently compact. I have had some fantastic views with this scope.

Jay Hardin
Star Route
Ilwaco, WA 98624

Help!

Dear Sirs / Recently I made a 12″ Wright camera, but am having trouble cutting sheet film to use in same. So may I make an appeal through your letters section for anybody with ideas on cutting 2.125″ disks out of square sheet film to suit my camera. Any ideas would be very welcome.

W.C.Trice
136 Edith Avenue
Peacehaven
East Sussex
BN9 8EB England

— Several years ago, your Editor made a die cutter for his Schmidt camera that cut 1″ circles out of 35mm roll film, which is on considerably thinner stock. It consisted of two 2″x2″x¼″ pieces of mild steel with a 0.010″ shim between, pin-registered and held together with machine bolts, then bored with a hole 1.0000″ diameter. The die was a 0.9998″ diameter by 2″ length of mild steel rod turned until it fit the bore. To use, I inserted the film in the jig, inserted the die, tapped it gently with a hammer, and a circle of film would fall out the bottom. Readers with relevant experience cutting sheet film should contact Mr. Trice directly.

Vulcan Surplus

Dear Richard / In the course of a search for parts for some Dobsonians I'm building, I stumbled upon what I consider to be the ultimate in altitude bearings for this type of scope. These are *solid Teflon* rings, 9.5″ O.D., 1″ wide and thick with 12 holes evenly spaced around their circumference. They were unused industrial surplus

►

Master Optical Techniques
by Arthur S. DeVany
Published by John Wiley & Sons, 1981, as part of the Wiley series in pure and applied optics. 600 pages.

Anyone who has worked in optics as an amateur or professional in the past two decades should be familiar with the writings of master optician Arthur S. DeVany. His work has appeared in both professional journals and telescope making columns in astronomy magazines, presenting valuable testing and fabrication techniques for the readers of these publications.

Now, at long last, DeVany has collected his works in a book, as he says in his preface, for "those who want to learn the techniques of the master optician," a book in which "students, teachers, and practicing opticians will find . . . practical development of the techniques and operations involved in the fabrication of prisms, lenses, and aspherical optical elements." Perhaps the paramount question for the TM is: Is this material of practical value — especially since much of it dates back two decades?

The answer is an unequivocal "yes." That many of the techniques are now "tried and true" and have been applied for many years does not condemn their publication; all are valuable fabrication methods. Some professionals in the optics field may not want this book — but that's because they already have the material from the optical journals in their files. For the amateur telescope maker, much will be new; and it's from this point of view, but with my background as a professional in optics, that I review this book.

The book is divided into four parts, each containing many chapters. Part I has 5 chapters and 68 pages; Part II has 13 chapters and 186 pages; Part III has 6 chapters and 83 pages; Part IV has 5 chapters and 118 pages. There are 22 special appendices with a total of 118 pages containing a wealth of working information and ideas. Accompanying the appendix listings are 3 pages of references followed by 8 pages of index information.

Many may wonder just what skills and abilities one requires to work in optics and ultimately become a "master optician." The first chapter lists some of the skills needed in an optical shop: 1) maintenance of equipment, work area, records, schedules, and development of safe working methods; 2) operation of equipment such as generators, glass saws, edgers, hand spindles (for roughing), and fine grinding, polishing, and coating machines; 3) production of precision diameters, radii, thickness, angles, and parallelism on optical components; 4) testing of optical flats, radii, physical dimensions, angles, and optical quality with monochromatic light, micrometer, spherometer, lens bench, and autocollimators; 5) accurate use of autocollimators, optical test bench and related gear, interferometer, and Ronchi and knife-edge tests in maintaining tolerances and testing for optical properties; and 6) construction of test set-ups for the inspection of polishing and figuring operations and interpretation of tests.

DeVany also points out that knowledge of the fundamental theory of light, the principles of refraction and diffraction, the characteristics of glass, procedures for processing glass or optical material from rough parts to finished product, elementary math, interpretation of blueprint specifications, tolerances, and tests of components at various stages of development are invaluable to the working optician.

Of course, in addition to all these requirements, the optical technician must develop professional pride in meeting the exacting tolerances of his trade and master the basic skills applicable to each phase.

Before considering further the valuable contents of this book, the amateur should carefully consider these points and decide if he or she is interested enough to acquire the necessary background and skills. If he or she is not, then this book will be of little value.

If that *is* you and you want to learn advanced means of optical fabrication either as a hobby or for a future business or profession, let's consider the salient points that will help and, hopefully, inspire you.

In Part I, after learning the role of an optical technician, Chapter 2 introduces Basic Operations. Here, you get a tour of the various professional glass working machines and their operation. Of great importance to an optician is hand polishing and figuring. Chapter 3 describes various hand procedures and gives formulae for making up special figuring laps. Chapter 4 outlines the testing of flat and curved test plates and their fabrication. He describes methods of correctly viewing fringe patterns between a workpiece and a master flat and how to use test equipment properly for this work.

One requirement in an optical shop (or for that matter, for an amateur astronomer interested in turning out good quality optics) is checking a piece of optical glass for internal quality. Chapter 5 describes how to do this using interferometric equipment and auxiliary optics.

Part II discusses the fabrication of prisms and lenses. If you are an experienced amateur telescope maker, you may have made a compound telescope with a parabolic and hyperbolic mirror. This is an accomplishment of which you may justifiably feel proud. But if you are seeking a greater challange, why not try making a precision prism? Holding the flatness of the surface while correcting the tilt of the surface being worked relative to the remaining surfaces is a challenging task and one guaranteed, as the saying goes, "to separate the men from the boys"!

Chapters 6 through 14 describe many common prism types and their working. The worker does not need the magic laser in the testing — a small autocollimating telescope does the work when applied properly. An autocollimator is a telescope with a reticle pattern at its focus so the image of the reticle emerges in a parallel light beam. Upon the beam's return from a reflecting surface, it passes through the system to a viewing eyepiece and reticle for measurement. This is one of the most useful tools used in testing in a professional optical shop.

With curved surfaces, such as one has on lens elements, the figure and radius control is achieved by the use of spherical test plates. Their fabrication and use are described in Chapter 15.

To make lens surfaces, the required equipment is described in Chapter 16. The tooling methods will help the amateur in this type of optical surfacing.

Part III, Telescope Systems, naturally holds the greatest interest for the amateur. Special types are described in the six chapters in this section. Working and Testing Off-axis Paraboloids (Chapter 19) outlines how professionals make these special optics — and how you can duplicate their efforts. It is a well-known fact that unobstructed instruments give the highest contrast and resolution for their size.

Testing and Making Short Focus Paraboloids, Chapter 20, employs the time-honored test method of an auxiliary telescope to test the short focus one.

Chapter 21, on Schmidt Cameras, is a subject always of interest. The first Schmidt camera made in the United States was done by an amateur for a local observatory! In the 22 pages of this chapter are found formulae and fabrication methods for producing a correcting plate for such an optical device.

Perhaps the most difficult optical systems are solid Schmidt cameras. Chapter 22 reveals some of the working methods used in their fabrication. Off-axis solid Schmidts can be made down to f/0.35 — but are a most trying job for even a master optician.

If the curves on the primary and secondary are equal, then a compound telescope will have a flat Petzval surface — unlike the commercial variety which have curved focal surfaces. In 1965, DeVany published his design for a Schmidt-Cassegrain having such a field. Chapter 23 gives the parameters for such an instrument with working methods. One of the most interesting parts of this chapter is a description of how one can turn a drill press into an optical surfacing machine for making this instrument! This chapter also describes how to make a paper pattern for pressing a lap to control the figure.

Chapter 24 contains instructions on how to make a plano interferometer with an aspheric lens — eliminating extra correcting optics in the tester.

Part IV describes Optical Testing. These four chapters begin with Chapter 25, a description of a "Universal Tester" with applications in most optical testing situations. A microscope objective with a pinhole at its focus and a beamsplitter lets the worker test and measure the steep curves on lens surfaces and also presents an unresolvably small image just in front of the objective that allows one to examine the returning image from an optical system for spurious disk and diffraction ring performance.

Chapter 26 contains an analysis of the Foucault knife-edge test. Just about anything an amateur would want to know can be found in this chapter; it is probably the most valuable section for amateurs in the book. The importance of this chapter is underscored by the fact that it runs some 63 pages. Pages 402 through 410 contain information on making a mask to test a 12" f/5 mirror, then how it was worked and analyzed to high perfection — and should serve as a valuable guide.

Very few amateurs test Achromatic Lenses (Chapter 27) but if one wants to, this chapter will be of great value.

The single-wire test was outlined in TM #6, page 40, and in his Chapter 28, DeVany discusses this test and his development of a double-wire test.

Few amateurs have the opportunity to use lasers in testing their mirrors — hence do not get to view interferograms or need to know how to interpret them. However, lasers are an important part of professional shop testing. The reader can familiarize himself with them by studying Chapter 29. Page 454 has Ronchigram patterns for both refracting surfaces and reflecting surfaces — and stresses to the worker that patterns are reversed in the refracting surfaces relative to the location of the grating (inside patterns for refracting surfaces are outside focus patterns for the reflecting).

The last 118 pages of the book comprise 22 appendices covering a wealth of information relative to fabrication and testing. With the prevalence of pocket calculators used by technicians in their work, and the simplicity of the formula, the angular settings for radius generating tables in Appendix 13 hardly seem necessary. They are probably of little use to anybody in my estimation.

If I had only one major criticism to make of this book, it would be that the proofreading is poorly done. There are four double-spaced pages of corrections to make things right. While most errors are obvious, some affect the analysis figures presented. However, the excellent information in this book offsets this problem. Once you go through it and mark the corrections, you'll have no trouble in using it.

This book goes far in aiding the beginner intent on a career in professional optics. For the advanced amateur, it has extremely useful parts. If you understand the aims and methods presented, you'll be on your way to reaching a final goal — Master Optician!

Robert E. Cox

■

Letters

items, and I purchased all I could lay my hands on. These rings give my scopes a smoothness of movement that surpasses that of any other material I've ever used (P.V.C., aluminum, etc.).

To finance my next mirror, I've decided to re-sell a few pairs (six only) and would like to see them find their way into the hands of some TMs who'd appreciate their potential. I'm asking $28.00/pair ppd. in U.S. ($4.00 above my cost) and would prefer to limit sales to one pair per individual. By the way, TM got me started in the Dobsonian field. Keep spreading the word.

Patrick M. Tatano
71 Van Buskirk Ave.
Stamford, CT 06902

— I am pleased to see that somebody else knows about Vulcan. I've been buying stuff from them since I was in high school. I saw those bearings in their shop, too, and had planned to run their address so that other interested TMs could snatch up a pair or two. It is: Vulcan Surplus, 64 Sunnyside Avenue, Stamford, CT 06902. Since I paid $4 for a pair of those bearings, it sounds like they figured out there was a market for them!

A Letter from Sherm

Dear Richard / The enclosed was printed this a.m. (not by me) and I wanted to send a print to you to show you we don't let the grass grow under our feet...there is too much 80 and 50 grit for grass to grow in anyway!

As you can see, I'm just pouring another spoonful on the surface of the segmented 36 incher. It is now being rough-ground to even out all the little inequities left over after epoxying the five

48 ►

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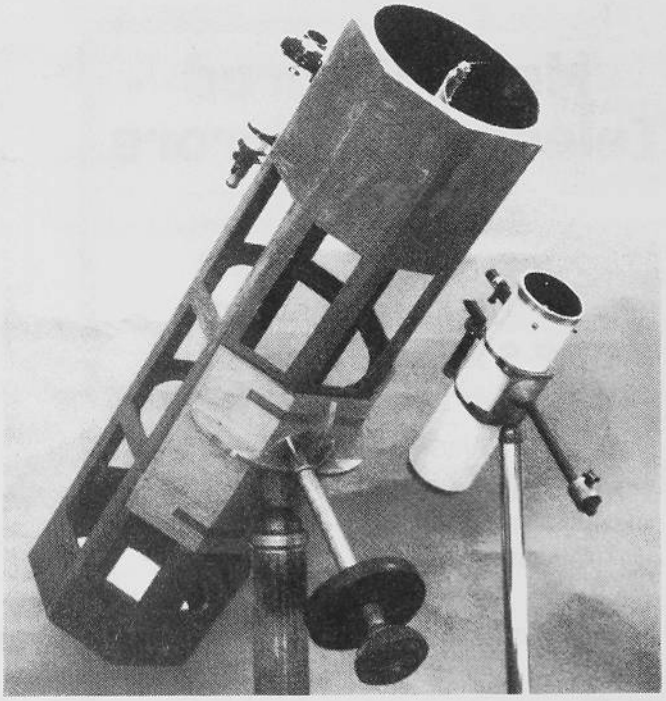

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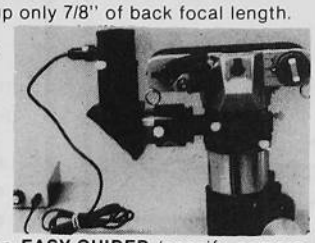

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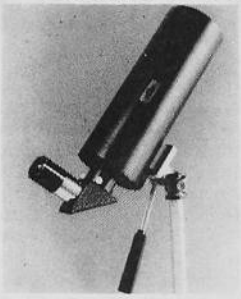

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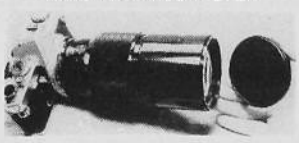

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Letters

◄41

12″ squares and the four corner fill-in pieces together. One advantage we've found is no big sagitta to hollow out from a flat surface. The f/3 curve is pre-ground into each segment prior to assembly and the whole shebang assembled over a mold with convex curvature of appropriate value. No heat sagging, furnaces, or molten glass for us!

And this blank is light even with its backing structure. You can see just part of the 3″ deep ribs that surround an 18″ square plate epoxied to the central plate which allows the overhung area to be melded into the main central structure. The second close-up of the tri-tool idea in action also shows the vertical members better.

Oh yes, no big one-piece tools, either. There are three easily obtained 8″ diameter tools, ceramic tile faced, articulated together with that triangular connection, made simply of ¾″ plywood and proper pinning. They flow with the curve, are easy to make, easy to handle, no heavy awkward tools to drop on the main mirror.

Hey, man, THIS is the route for big amateur mirrors.

Don't ask me about coefficients of expansion differences, don't ask me how strong the epoxy, you wouldn't believe it if I told you. The bond may last forever; I certainly won't.

The machine was in operation when the strobes went off — you can see the swath left by those tools on the overview shot. Since these were taken, I have added 8 pounds of weight on top of each of the tool holders in addition to the weights seen.

Some one of these days, after a cleanup, I'm gonna see how many quarts of water it takes to fill up that sagittal volume! That's the rough grinding I have saved time on. There's about 14 hours of rough grinding in it so far and at the rate it's going, no more than 10 more to go before we're ready for -120 grit. Let us say only 25 hours to rough grind a 36″ f/3 curvature? Not shabby.

I'll keep you up to date.

Sherm Schultz
Director
Observatory-Planetarium
Macalester College
Saint Paul, MN 55105

— Gee Willikers!

Those of you who did not realize something was wrong with the Texas star party article in TM-17 didn't read it. The type for the page 10-11 spread is all mixed up. It hops from column 1 to the middle of 3, then from nearly the end of 4 to the start of 2, etc. And our titles for it and Stellafane headline were a year ahead of their time — for your viewing pleasure, we present the correct year:

82

Two things really decided me: I was curious whether George could really pull it off. A meeting of the size and complexity George described is no easy task even for a Texan. And also, by attending I could cover new and interesting developments on the telescope front for TM.

Thus it came to pass that on May 25 I boarded an American Airlines flight to Dallas, where George joined me in the final flight to Midland-Odessa. There a group from Dallas was waiting with a station wagon to drive us to Ft. Worth, some five hours away. The weather had been bad in the Midland-Odessa area, but as we went west, we drove through a sand dune area where it had been worse — the ground was white with hail. A lot had melted, but we estimated that originally some hailstones must have been the size of golf balls!

Weather, which had been bad in the Ft. Worth area for days before the meeting, was the prime topic of discussion during the drive. Good news had arrived just before our drivers had left — indications on radar maps on cable TV indicated clearing was about to take place. Fortunately, this was the case — we did have clear skies each evening even though atmospheric stability was poor.

Leave it to those Texans to do things right. The Texas Star Party is a star party above all else, and, gosh darn, they said, we aren't gonna let any lights interfere with the observin'.

No car lights were allowed after darkness had fallen. All windows were blacked out on all buildings. All flashlights had to be fixed to only emit red light.

When we arrived at the Prude Ranch about 9:30 p.m., the blackout was already in full swing. I did manage to find my sleeping quarters and then wandered out with my red flashlight into the lower telescope field to see what early arrivals had set up to view in these dark skies of Texas.

A thin crescent moon hung low in the western sky about 70 minutes from setting — barely detracting much from views of deep-sky objects in the many telescopes. As soon as I spotted Omega Centauri — naked-eye — a good distance over the mountains to the south, I stumbled around to look for the largest telescope that I could find. It fortunately turned out to be a home-mounted 17.5-inch Dobsonian — and it just happened to be looking at the cluster.

I asked to share the view, then stepped up to the eyepiece to encounter an experience that words can never adequately describe. Time went by. My eye was literally glued to the ocular until the instrument maker offered to reset the telescope — but I assured him that I could operate a Dobsonian. Time continued to pass and I faintly heard someone in the background say, "Maybe he died; he hasn't moved in so long!"

Well, they literally had to drag me away from the eyepiece so others could take my place — but I'll never be the same again! Until you've seen the Omega cluster with an instrument of 17.5″ or larger — with it a satisfactory distance above the horizon — you haven't lived.

Aperture Envy!

Dear Richard / You may recall that in TM#16, you published a letter on an amateur one-meter telescope in Vienna, Austria, and you advised me to "look out" for deadly aperture fever. I am pleased to report that your kind advice has been ignored, and the Fairborn Observatory has launched out on a one-meter telescope project. Actually, the telescope primary will be 1.001 meters in diameter — a "silly millimeter" larger than the telescope in Austria.

This long-dreamed-of project became a reality at last when the University of Illinois agreed to provide a completed f/3 Pyrex mirror (they will share in the observing time), DFM Engineering agreed to design the telescope (similar to the designs for the 0.9m MIRA and 2.4m McGraw-Hill telescopes), Micro Source, Inc., provided the STD Bus computer, Whedco provided the critical STD Bus Intelligent Stepper Controllers (computers in their own right), and various other companies and individuals agreed to contribute key items.

You and all my fellow readers of TELESCOPE MAKING are cordially invited to the groundbreaking which will take place on July 15, 1983 at the Fairborn Observatory.

Russell M. Genet
Fairborn Observatory
1247 Folk Road
Fairborn, OH 45324

— Thank you, Russ, and glad to have my advice ignored! To those who haven't yet psyched this letter out yet, Russ is one of the moving spirits of the IAPPP, a group of photoelectric photometrists. The telescope will undoubtedly be used for photometry.